

ANNUAL REPORT

OF THE

DIRECTOR OF THE BUREAU OF STANDARDS

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1923

(Miscellaneous Publications—No. 53)



WASHINGTON
GOVERNMENT PRINTING OFFICE
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REPORT

OF THE

DIRECTOR OF THE BUREAU OF STANDARDS.

DEPARTMENT OF COMMERCE,
BUREAU OF STANDARDS,
Washington, July 2, 1923.

SIR: In transmitting this report of the work of the Bureau of Standards for the fiscal year ended June 30, 1923, it seems appropriate to call attention to the fact that the work of the first half of the year—that is, until January 1—was carried out under the direction of Dr. Samuel W. Stratton. Doctor Stratton was the first director of the bureau and served continuously from 1901 until the date above mentioned, when he resigned to accept the presidency of the Massachusetts Institute of Technology. From January 1 until April 21 Dr. Fay C. Brown served as acting director. On that date my appointment became effective.

I. INTRODUCTION.

FUNCTIONS.

Before considering in detail the work of the various divisions of the bureau it may be of interest to describe very briefly its functions and organization. The bureau is charged with the development, construction, custody, and maintenance of reference and working standards and their intercomparison, improvement, and application in science, engineering, industry, and commerce.

Classes of Standards.

Standards are divided into five classes, as follows: (1) Standards of measurement (measurements of length, mass, time, heat, electricity, etc.); (2) standard constants (the fixed relations between physical quantities which underlie scientific research and industrial processes, such as the mechanical equivalent of heat, velocity of light, ratio of electrical units, and the constant of gravitation); (3) standards of quality (specifications for material); (4) standards of performance (specification of operative efficiency of machines and devices); (5) standards of practice (codes for technical regulation of construction, installation, and operation of machines and devices, and for increasing the efficiency and safety of industrial processes).

ORGANIZATION.

The work of the bureau is necessarily of an extremely varied character, and for purposes of organization it has been found con-

venient to group together experts in similar lines of work irrespective of the class of standards dealt with. The bureau is therefore made up of 11 scientific and technical divisions, besides those concerned with the administration of the central office, the operation of the bureau's plant and construction work. Each of these divisions is under the direction of a division chief, and the work is further subdivided into sections, each section dealing with a particular class of problems.

Divisions of the Bureau.

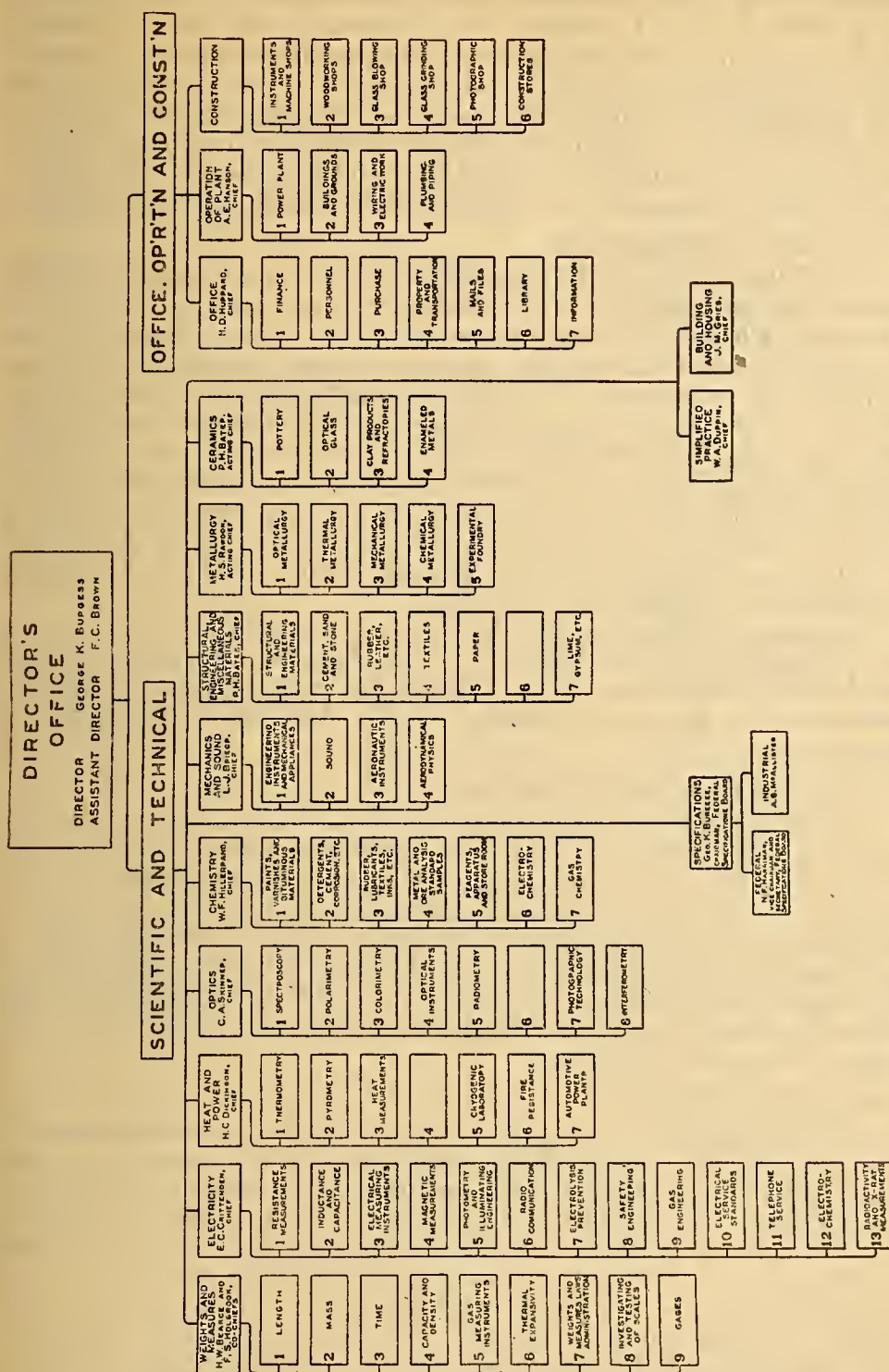
The plan of organization will be evident upon inspection of the accompanying chart. From this it will be seen that the scientific and technical divisions of the bureau deal with weights and measures; electricity; heat and power; optics; chemistry; mechanics and sound; structural, engineering, and miscellaneous materials; metallurgy; ceramics; simplified practice; and building and housing. Besides these scientific and technical divisions there will be noticed the office, operation, and construction divisions, and the work in connection with specifications, which includes the fields of Federal specifications and cooperation with States, municipalities, institutions, and industries. The Director of the Bureau of Standards is ex officio chairman of the Federal Specifications Board, organized by direction of the President and made a part of the Bureau of the Budget. Many members of the bureau's staff serve on the various committees of the Federal Specifications Board, and the results of their work during the past year will be found treated in reports of the various divisions. For further details of this aspect of specifications the annual report of the Director of the Bureau of the Budget should be consulted.

TESTS AND INVESTIGATIONS.

The bureau is required by law to carry out tests or investigations for the National or State Governments without charge, and in this connection it may be mentioned that the bureau has served for many years as a testing and research laboratory for practically every branch of the Government service.

In the case of individuals or firms, certain investigations are undertaken where the results would seem to be of benefit to the public, the bureau reserving the right to use the data thus found as it sees fit. Some routine testing is likewise conducted for private individuals or manufacturers where no commercial laboratory is fitted to perform the work, or where a dispute has arisen, all parties to the controversy having decided to refer the matter to the Bureau of Standards as a referee. In the case of test work performed for private parties, nominal fees are charged, which are turned in to the Treasury. With the exception above noted, nearly all the investigational work is carried out in cooperation with other Government departments or with industrial, technical, and scientific organizations, and very largely at the request of those for whom the investigations are made. This cooperative work is described in the following paragraphs. A list of tests and researches completed during the year will be found in the work chart immediately preceding the detailed reports of the different divisions, except, of course, those

divisions which from the nature of their functions do not carry on work of this kind.



Divisions and sections of the Bureau of Standards (June 30, 1923).

RELATION OF THE BUREAU TO AMERICAN INDUSTRIES.

It is particularly gratifying to note the closer relations which are growing each year between the bureau and the industries of the

country. Not long ago it was a matter of considerable difficulty to obtain the cooperation of industrial groups in the small amount of research work then carried on by the Government. Now problems are presented to us by almost every industry, and their successful solution depends very largely on the degree of cooperation between those presenting the problem and the bureau. The former are the best judges of the commercial aspects of the question and can give invaluable advice on the practicability of suggested processes, while the latter is best qualified to lay the sound foundation of scientific and technical data upon which the solution of such questions depends.

Cooperative Investigations.

As an illustration of the desire of industry to cooperate with the bureau, the investigation of welded rail joints may be cited. The American Electric Railway Association has raised \$23,000 for an investigation of this problem and has chosen the director of the bureau as the chairman of a joint committee having this work in charge. A test track and other apparatus with which to carry on the work are being installed at the bureau. The director has also been chosen chairman of the joint committee for the investigation of the effects of sulphur and phosphorus in steel, a problem of great economic as well as industrial importance; chairman of the annual conference of instrument manufacturers and users, and the annual conference on weights and measures.

The engineering public has also shown its confidence in the bureau by electing the director president of the American Society for Testing Materials and also of the Society for Steel Treating, and has made him an honorary member of the American Foundrymen's Association.

Conferences Held During the Year.

Approximately 100 conferences were held during the year, attended by representatives of industrial associations, the various branches of the Government, and the Bureau of Standards for the solution of fundamental problems and for the purpose of mapping out and directing cooperative research programs. Several of these meetings were held at the bureau, and in this way, besides discussing the immediate questions at issue, an excellent opportunity was afforded manufacturers and others to become acquainted with the bureau's research facilities.

Research Associates.

In line with this policy of closer cooperation a system of research associates has been worked out, and several of the most important industries are maintaining such associates at the bureau for carrying out particular investigations in which they are interested. In nearly every case these research associates are supported not by a single manufacturer but by a group through their trade association; and the results, which are published by the bureau, are available to the public at large. In this way the facilities of the bureau's laboratories and the experience of its scientific staff are made of benefit to the maximum number of people throughout the country, and incidentally men are trained for the industries in research methods. There are at present stationed at the bureau 21 associates, representing 18 industries. A list of these research associates, together with

the divisions to which they are assigned, the problems on which they are working, and the industrial associations represented by them, is given below.

RESEARCH ASSOCIATES AT BUREAU OF STANDARDS.

Name.	Assignment.	Duties.	Representing.
Coleman, Richard L., jr.	Weights and measures.	Dental materials.....	Weinstein Research Laboratory.
Birdsell, Roger...	Heat and power.....	Fuel research.....	Society of Automotive Engineers.
Eisinger, J. O.....	do.....	do.....	Do.
Foster, H. D.....	do.....	Investigation of fire resistance of hollow tile.	Hollow Building Tile Association.
Osborn, Nathan S.....	do.....	Steam-table research.....	American Society of Mechanical Engineers.
Prebble, M. E.....	do.....	Fuel research.....	Society of Automotive Engineers.
Munsell, A. E. O.	Optics.....	Color research.....	Munsell Research Laboratory.
Brown, W. B.....	Structural engineering and miscellaneous materials.	Loading tests of corrugated zinc roofing.	American Zinc Institute.
Dutton, H. H.....	do.....	Researches on limestone.....	Indiana Limestone Quarrymen's Association.
Gottschalk, V. H.....	do.....	Glue investigations.....	National Association of Glue and Gelatine Manufacturers.
Porter, J. M.....	do.....	Gypsum investigations.....	National Gypsum Association.
Schenke, E. M.....	do.....	Hosiery and underwear investigations.	National Association Hosiery and Underwear Manufacturers.
Stockett, J. W.....	do.....	Researches on lime.....	National Lime Association.
Aungst, W. M.....	Metallurgy.....	Researches on molding sands	National Foundrymen's Association.
Cain, J. R.....	do.....	Metallurgical researches.....	Trcnt Process Corporation. American Rolling Mill Co. Metal & Thermit Co.
Ruh, E. W.....	do.....	Nickel-alloy researches.....	International Nickel Co.
Waltenberg, R. G.....	do.....	Malleability of nickel.....	Do.
Ford, K. L.....	Ceramics.....	Glass investigations.....	National Glass and Containers Association.
Fuller, D. H.....	do.....	Terra-cotta researches.....	National Terra Cotta Society.
Gaardsmoe, H. L.....	do.....	Investigation of cement wall tile.	Associated tile Manufacturers.
Roehm, V. J.....	do.....	Study of raw materials in potters' manufacture.	Homer-Laughlin China Co.

PUBLICATIONS.

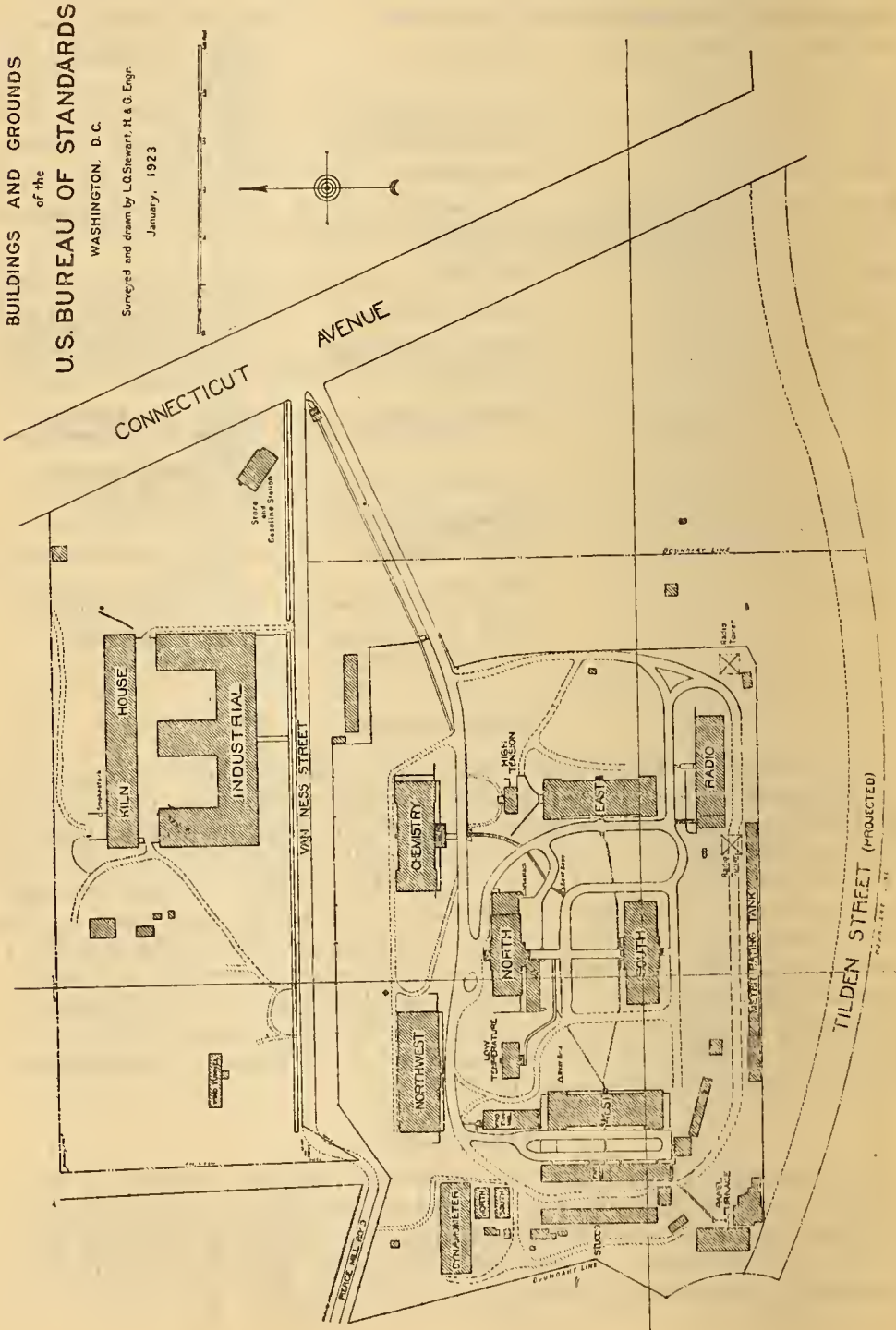
The results of the bureau's work are made available through its publications. Those issued during the past year in the various series of the bureau, as well as articles prepared by members of the bureau's staff and published in outside journals, will be found listed at the end of each divisional report and, where the publication ties up with some particular investigation conducted during the past year, in the work chart above mentioned. Consultation of these publications is recommended in cases where the reader desires more detailed information concerning the work. The publications of the Bureau of Standards are listed in Circular 24 with its supplement, and they can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C.

LOCATION.

The bureau is located near the corner of Van Ness Street and Connecticut Avenue NW., and is reached by the Chevy Chase car line. It is made up of a number of buildings, each designed for some particular class of work. A map of the bureau's grounds, showing the location of the various buildings, is given herewith.

Branch Laboratories.

The bureau maintains branch laboratories for the inspection and testing of cement and miscellaneous building materials at San Francisco, Calif.; Denver, Colo.; and Northampton, Pa., in order to expedite the work in the territory in which they are located. These laboratories have been functioning efficiently during the past year.



II. REPORTS OF THE SCIENTIFIC AND TECHNICAL DIVISIONS.

WEIGHTS AND MEASURES.

H. W. Bearce, F. S. Holbrook.

FUNCTIONS.

The division of weights and measures is charged with the custody of the National Standards of the United States and with the task of spreading abroad their influence and of carrying them to as great an extent as is necessary into the scientific, industrial, and commercial life of the Nation. The division is thus concerned with research and measurements involving the fundamental units of length, mass, and time, and with derived or secondary units, such as area, volume, density, and pressure. The activities of the division also include the enforcement of certain Federal weights and measures laws, the preparation of specifications and tolerances for use in connection with standardization of weighing and measuring apparatus, gauges, and screw threads; cooperation with States in the preparation and enforcement of weights and measures legislation, and in administration of weights and measures departments; the design, improvement, inspection, and method of test of weighing and measuring apparatus, both precise and commercial; the carrying out of researches designed to result in more accurate knowledge of physical constants; and improvements in engineering practice.

SECTIONS.

- 1. Length.
- 2. Mass.
- 3. Time.
- 4. Capacity and density.
- 5. Gas measuring instruments.
- 6. Thermal expansivity.
- 7. Weights and measures laws and administration.
- 8. Investigation and testing of scales.
- 9. Gauges.

GENERAL STATISTICS.

Staff	45
Expenditures (1922-23)	\$117, 000
Tests completed	30, 431
Researches completed	8
Bureau publications issued	4
Other technical publications	2

WORK CHART.

1. LENGTH.

SCOPE.

Preservation and comparison of the national prototype meter and its copies.
Development of methods and apparatus for length measurement.

Comparison of State, municipal, and other standards of length with the national standards.

Preparation of specifications for instruments and materials requiring linear dimensions of a definite and stated accuracy.

Test of instruments and materials to determine conformity to specifications.

Measurements of length of a miscellaneous and varied character, including study of conditions of use of apparatus and precision and nature of test required.

Obtaining, compiling, and distributing to manufacturers and others information regarding methods of length measurement.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Cover glasses for hæmacytometers.....	540	244
Hæmacytometers.....	276	388
Invar base line tapes.....	19	62
Invar strips.....	20	13
Length standards and precision scales.....	9	9
Level rods.....	34	61
"Metallic" tapes (cloth).....	104	74
Miscellaneous articles.....	73	45
Sieves (for cement, sand, etc.).....	111	385
Sieve cloth.....	14	5
Steel tapes.....	157	136

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Methods of precision length measurement employed in Europe.....		90	
Investigation of character of surfaces and defining lines on yard and meter bars.....		100	
Investigation of methods of graduating invar tapes.....		100	

2. MASS.

SCOPE.

Custody of national standards of mass.	Improvement of standards of mass.
Testing standard weights.	Improved methods of weighing.
Testing precise balances.	

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Weights:		
Class A.....	98	57
Class B.....	51	23
Class C.....	156	172
Class M.....	182	616
Class S.....	4,488	5,259
Special.....	395	573
Balances.....	10	33

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Lacquered weights: Changes with humidity and wearing qualities.....		50	
Metals suitable for weights: Stainless steel, stellite, rezistal, rustless steel, and tantalum.....		10	

3. TIME.

SCOPE.

Test and certification of time-measuring devices.

Researches on time-measuring devices.

Service on committees of organization whose object is improvement in the construction, test, use, and repair of time-measuring devices.

Answering inquiries with reference to time-measuring devices and related and miscellaneous subjects, such as standard time belts, calendar reform, etc.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Watches (railroad precision test).....	181	551
Stop watches.....	51	20
Chronometers.....		7
Miscellaneous.....	2	1
Special war work (completed during 1922).....	1,819	

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Designing and experimenting with new types of time-measuring instruments.....		Continuing.	
Study of results of tests of watches with a view to correlating time-keeping qualities with type, grade, and retail price.....		do.....	

4. CAPACITY AND DENSITY.

SCOPE.

Testing of capacity and density apparatus.

Design, improvement, and calibration of special volumetric apparatus.

Determination of density and volume coefficients of liquids, and the preparation of tables based thereon.

Assistance to manufacturers of apparatus by conference and by correspondence.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Apparatus:		
Volumetric glassware.....	14,328	9,115
Hydrometers.....	563	925
Capacity measures.....	85	77
Density.....	114	303
Miscellaneous.....	152	377
Weight of samples.....		72

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Density and thermal expansion of sodium chloride solution.....		90	
Density and thermal expansion of sea water.....		75	
Density changes produced in glass by various heat treatments.....		25	
Density and thermal expansion of denatured alcohol.....		10	

5. GAS-MEASURING INSTRUMENTS.

SCOPE.

Tests of gas-measuring instruments.

Conduct of researches on gas-measuring instruments.

Service on committees whose functions are to specify standards for the construction, testing, and using of gas meters.

Preparation of publications on gas-measuring instruments and methods.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Portable cubic-foot bottles.....	8	3
Dry meters.....	38	3
Wet meters.....	5	1
Spirometers.....	9	6
Special devices.....	29	1

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Investigation of orifice meters.....	Army.....	33	

6. THERMAL EXPANSIVITY.

SCOPE.

Experimental determination of thermal expansivity of solids.

Study of transformation regions when accompanied by length changes.

Determination of dimensional variations incident to heat treatment; for example, distortion with time or temperature or both.

To advise regarding the propriety of combining different materials in structures, apparatus, etc.

The ruling of scales and production of screws of high precision.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Aluminum alloys.....	32	19
Nickel steel.....	10	2
Dental investments and waxes.....	24	3
Valves and miscellaneous steels.....	8	4
Enamels and glasses.....	17	38
Lead-antimony alloys.....		13
Gold alloys.....		11
Miscellaneous.....	32	16

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
The effect of mechanical working and heat treatment on the structure and the thermal expansion of molybdenum.....		100	
The thermal expansion of aluminum and some of its important alloys.....		50	
The thermal expansion of lead-antimony alloys.....		25	
Designing and installing equipment for testing errors in screw threads.....		25	
Designing and installing apparatus for cutting screws to an accuracy of one-millionth of an inch.....		25	
Testing the effects of lubrication upon moving parts of a dividing engine.....		25	
Designing, assembling, and testing bearings suitable for use in precision apparatus.....		25	
Determining the effect of cumulative errors.....		25	
Designing and installing equipment for determinations of: Shrinkage of cast alloys, effects of pressure on castings, setting changes of investments, porosity of investments, distortion and elimination of wax patterns, flexure-life tests of wire, clasps, etc.....		10	
Determinations of melting points, thermal expansion, elasticity.....		50	

7. WEIGHTS AND MEASURES LAWS AND ADMINISTRATION.

SCOPE.

Cooperation with State and local weights and measures departments.
 Cooperation with manufacturers of weighing and measuring devices.
 Conduct of investigations and surveys on weights and measures matters.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Liquid-measuring devices and attachments.....	7	7
Heavy-duty automatic scales.....	107	2
Postal and other scales.....	10	9
Scale-testing devices.....		1
Leather-measuring devices.....		4
Barrels.....	6	38
Filling of milk and cream bottles.....		3,610
Weighings of loaves of bread.....		2,613

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Types of commercial weighing and measuring devices.....		Continuing.	
Enforcement of Federal standard barrel law.....		Continuing.	
Filling of milk bottles in commercial practice.....		100	
Weight variations and shrinkage of loaves of bread.....		100	
Leather-measuring machines.....		50	
Spring balances for tape stretching.....		60	
Specifications and tolerances for household measuring cups.....		85	
Specifications and tolerances for heavy-capacity automatic scales, vehicle tanks, and fabric-measuring devices.....		60	
Hysteresis effect on coiled springs for weighing scales.....		15	

8. INVESTIGATION AND TESTING OF SCALES.

SCOPE.

Calibration and maintenance of accuracy of master track scales.
 Investigation of railroad track scales.
 Calibration of test cars.
 Investigation of mine scales.
 Development of specifications and tolerances and methods of tests for, and capacity rating of, master track, railroad track, grain hopper, and other heavy-capacity scales, and of testing machines.
 Development of weighing methods for heavy-capacity scales.
 Calibration of heavy weights.
 Cooperation with railroads, weighing bureaus, etc., on heavy-capacity scale and weighing problems.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Master track scales.....	17	19
Railroad track scales.....	894	636
Railroad test cars.....	38	16
Mine scales.....	129	140
Other heavy-duty scales.....	28	37
Spring scales, dynamometers, etc.....	21	16
Devices for determining wheel loads on automobile trucks.....	4	2
Testing machines.....	3	0
Film-measuring devices.....	0	3

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Master track scales.....		Continuing.	
Railroad track scales and test cars.....		Continuing.	
Mine scales.....		Continuing.	
Conveying weighing scales.....		20	
Specifications and tolerances on motor truck built-in, self-contained, and portable scales.....		100	
Specifications and tolerances for hand-operated grain hopper scales.....		75	
Methods for testing heavy-capacity hopper scales.....		50	
Analysis of existing tolerances on track scales.....		100	
Discrepancy between mine scale and railroad track-scale weights.....		10	
Nature of reactions in 4-section track scales.....		50	

9. GAUGE STANDARDIZATION.

SCOPE.

Determination of dimensions of master, inspection, and working gauges used in interchangeable manufacture.

Development and construction of apparatus for measuring or checking gauges and the manufacture of gauges for experimental purposes.

Collection of data on stock sizes, standard dimensions, and tolerances for common metal shapes and machine elements.

Cooperation with engineering committees or commissions engaged in standardizing sizes of and tolerances for machine elements, such as the American Engineering Standards Sectional Committee on Plain Limit Gauges, The Gauge-Steel Committee, and National Screw Thread Commission.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Plain plug, ring, snap, and flush pin gauges.....	1,048	280
Thread gauges.....	238	284
Profile gauges.....	5	17
Instruments measuring by contact.....	48	37
Precision gauge blocks.....	979	752
Test specimens for gauge-steel investigation.....		2,185

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Gauge-steel investigation: Measurement of dimensional changes in specimens made of several grades of steel to determine changes due to annealing, hardening, tempering, and with time.	40	Special reports.
Investigation of the effect of errors in thread form, lead, and taper on the tightness and strength of pipe joints.	90	
Investigation of the suitability of stellite as a material for gauges.	90	
Search for a suitable method of checking the light interference method of comparing and determining parallelism of precision gauge blocks: Study of condenser plate micrometer for this purpose.	10	
Study of commercial dial micrometers used in the measurement of the thickness of paper.	100	T226.

Detailed Report of the Year's Work.

1. LENGTH.

L. V. Judson.

The work carried on by this section during the past year has included a large amount of routine testing, the calibration of laboratory equipment, and an extended study of the apparatus and methods employed in foreign standardizing laboratories similar to the Bureau of Standards, especially the International Bureau of Weights and Measures.

Tests.

Among the tests of major importance may be mentioned the following: (*a*) Tests of invar base-line tapes of the United States Coast and Geodetic Survey, especially the graduation, calibration, and determination of coefficient of expansion of a series of tapes used in measuring a base line to be used by Prof. A. A. Michelson in a re-determination of the velocity of light; (*b*) tests of 12 invar base-line tapes submitted by the Argentine Naval Commission; (*c*) measurement and selection of a standard set of sieves for the Bureau of Standards; (*d*) measurement of rulings and standardization of measuring apparatus used by a manufacturer of haemocytometer counting chambers who was having difficulty in duplicating results.

Calibration of Laboratory Equipment.

During the year much time and attention were devoted to the recalibration of the laboratory's testing equipment. As a result, the work turned out by the section is of a higher average accuracy than ever before. The work on geodetic tapes has been especially gratifying, the probable error in the certified lengths of these tapes being only about one-fourth that of a few years ago.

Study of Methods and Equipment Used in European Laboratories (Judson).

The chief of the length section, spent the greater part of the year abroad in studying the methods and equipment used in other

standardizing laboratories similar to the Bureau of Standards. His time was largely spent at the International Bureau of Weights and Measures at Sevres, near Paris, with visits also to the national standardizing institutions at Teddington, England; Berlin, Brussels, Berne, and Rome.

Methods of precision measurement as well as the design and use of precision instruments were carefully studied, and the information and experience gained should be of the greatest value to the bureau.

Return of the United States Primary Standard of Length.

National prototype meter No. 27, the primary standard of length of the United States, was brought back from the International Bureau of Weights and Measures, where it had been taken for recomparison with the international standards.

It is extremely gratifying to note that the recent recomparison of this primary standard of length with the international standard shows that our national standard has remained constant in length within the errors of the most precise measurements since its original comparison in 1889, before it was allotted to the United States. A slight apparent change reported in 1903 has been found to have been due, in part, to a change in the laboratory standards with which it was then compared, and in part to the use of a coefficient of expansion which was slightly in error.

Need of New Apparatus.

The apparatus most urgently needed in order more effectively to carry on the work in the field of precise measurement of length is listed below in what is considered to be the order of urgency:

1. *Longitudinal comparator*.—The need of a longitudinal comparator for calibrating the intervals of line standards up to 1 meter in length has been emphasized in the annual reports for several years. Various makeshift methods have been used for this work, which by their very nature introduce slight errors, and thus prevent work of the highest precision on the bureau's own standards. This is an apparatus which would be in almost constant use, and one which is found in nearly every national standardizing laboratory. During the past year a large amount of information has been obtained which will enable the bureau to draw up specifications covering an instrument equal in accuracy and convenience to any now in use. The increasing demands for high accuracy from commercial concerns make the need for this instrument more imperative than ever.

2. *Linear dividing engine*.—In connection with the researches of this bureau and of other Government laboratories there is often a demand for special scales and line standards of a character which commercial concerns are not in position to produce. This work is often of an experimental nature and in many cases requires high precision. For investigational work of the length section itself there is also the need for such an apparatus. With the present tendencies toward higher precision in the industries this need increases. Fundamental researches now being carried on in this division and described under section 6, on the basic problems underlying dividing-engine design will be continued with the object of constructing a precise dividing engine of this type.

3. *Circular dividing engine.*—The need for a circular dividing engine is very similar to that for the linear engine. Indeed much of what has been said of the linear engine applies equally in the case of the circular engine. It is believed, however, that the linear engine is somewhat more urgently needed than the circular.

4. *Circle testing device.*—As a preliminary requisite to the circular dividing engine, there should be provided a circle testing device. This will be required to thoroughly test a specimen circle of any dividing engine manufacturer before it would be advisable to place an order for the dividing apparatus. The need for this apparatus is a very concrete one—two precision circles are now on order by other divisions of the bureau, and on delivery these will require a precision test for acceptance. The graduating and testing of circles required by the Coast and Geodetic Survey also emphasize the need for both the circular dividing engine and the circle testing device.

2. MASS.

A. T. Pienkowsky.

Standards of the Bureau.

The testing of the standards of the mass section, begun last year by comparisons with the fundamental mass standards of the United States, was actively continued during this year, and tests upon all of the more important working standards have been completed.

Study of Lacquer for Weights (Pienkowsky).

During the year there has been carried on an extended study of the lacquers which may be employed for coating weights, in relation to the constancy of the weights. Three kinds of material have already been studied—a nitrocellulose lacquer, a bakelite preparation, and a spar varnish. An attempt to use linseed oil as a lacquer substitute was not successful, because the oil used could not be made properly to cover the polished metal.

It has been determined that it is necessary to bake weights coated with any of the above lacquers in order to prevent progressive changes that otherwise would take place over a long period of time. It is also necessary to use thin coatings because thick coatings are found to be too much affected by changes in the humidity of the air.

Sets that have been prepared in various ways have now been in use for over a year and are being retested. The experience of another year should yield information that will be of great value to makers and users of this class of weights.

The relacquering and readjusting of weights used by the chemistry division has been continued, and 27 such sets have been put in good condition during the year.

Materials for Weights (Pienkowsky).

An investigation is now in progress of various alloys to determine their suitability for making weights of different classes. One sample of stainless steel was found to be unsatisfactory, especially for the more precise weights, because it was magnetic and also corroded to such an extent that it was of doubtful value. A number of samples have now been prepared from other alloys, and some tests as to constancy in ordinary atmosphere and also in the somewhat acid air of one of the chemistry laboratories have been begun.

Assistance to Manufacturers (Pienkowsky).

The bureau is able to be of very great assistance to manufacturers of weights in helping them to improve their product. In a typical case a careful tabulation of all weights tested for one manufacturer during about six months was made and studied in order to locate the source of inaccuracies experienced for some time. On the basis of this study suggestions were made which enabled him to locate and eliminate this trouble.

In another case several successive samples of weights submitted by a contractor to the Post Office Department were found not to conform with the specifications, upon their submission to the bureau for test. The manufacturer was finally requested to submit drawings, and these enabled the bureau to suggest changes necessary to enable the manufacturer properly to construct the weights in question.

Handling Sets that Contain Inaccurate Weights.

Since the discontinuance several years ago, on account of the expense involved, of the general practice of holding sets of weights to allow the replacement of those found incorrect, manufacturers found it necessary in many cases to have almost a whole set retested in order to make the replacements and furnish a certified set. While this has undoubtedly helped greatly toward the improvement in accuracy noted in last year's report, it has also increased manufacturing costs. In an effort to correct this condition the bureau has tentatively adopted the practice of removing the inaccurate weights and certifying the incomplete set. The maker or dealer can then have certified separately the weights needed to complete the set and can furnish the customer a certified complete set. The experience of the past months indicates that this scheme will probably furnish a satisfactory solution of the problem.

Tests.

The number of tests made, a total of 6,700 weights, is an increase of 24 per cent over that of last year and is the largest number ever made during a year. The actual amount of work accomplished is even greater than is indicated by the number of tests because of the large increase in the number of Class M standards submitted. The tests of such standards involve very much more work than those of any other class.

3. TIME.

A. F. Beal.

The work of the time section has been confined largely to the testing of pocket watches and to committee and advisory work in cooperation with the Horological Institute of America, while a smaller amount of time and attention have been devoted to the correlation of results of previous tests, investigational work, and miscellaneous calculations.

Committee Work (Beal).

The chief of the time section has served as a member of the executive committee of the Horological Institute of America as secretary of its board of examiners and certification committee. These

committees have held meetings at the bureau and also at Lancaster, Pa., New York, and Boston. The work of the bureau in cooperation with the Horological Institute was presented before the New York State Jewelers' Association and the American National Retail Jewelers' Association in addresses given by the chief of the time section.

Correlation of Results of Tests.

For several years practically all watches tested have been submitted to the "railroad precision" test. The results for all tested watches known to be new or practically so at the time of the test have been compiled for each type and make. These results are of considerable value, and this will increase as the results of more tests are added.

There also has been prepared an index for each group of watches tested at one time. This is of considerable value, but should be extended to cover not only the kind of test but also each feature of the watches. For example, there should be an index indicating the location in the records of all tests of watches with noncompensated or uncut balances, flat hairsprings, nonjeweled watches, 7-jewel watches, and other irregular features.

Standard Time.

An attempt has been made to compile an index giving the standard time used in every country and important group of islands in the world. This list is far from complete, but will be increased as additional data become available.

Diurnal Variation in Clock Rates.

An investigation on the diurnal variation of clock rates is being carried on in cooperation with the U. S. Naval Observatory. Small progress on this problem has been made owing to the urgency of other matters.

Time Signals Received by Radio.

Beginning January 1, 1923, the time signals from the Naval Observatory for checking up the bureau's Riefler clock were received by a specially built radio amplifier which operates the chronograph pen. Formerly this was done by the line telegraph signal. Prior to discontinuing the telegraph signal, the radio receiver had been tested for several months and a long series of telegraph-radio comparisons obtained. The results show a relative lag of about 0.10 second of the radio signal over the wire signal.

New Time Service in Bureau.

A special wiring system has been devised and installed whereby another laboratory can, by remote control, throw on the Riefler clock signal and receive the signal.

History of Weights and Measures (Gould).

The compilation of history and data regarding the standard weights and measures furnished to the various States and custom-houses of the United States Government since 1840 has been completed.

4. CAPACITY AND DENSITY.

E. L. Peffer.

Tests.

The results of the year's work show that of the volumetric glassware submitted for test 91 per cent was eligible for test. The remaining 9 per cent was rejected upon preliminary examination on account of inferior material, workmanship, defects, or failure to comply with the specifications. In general, the quality of the glassware was better than in the previous year. The improvement was especially marked in the case of American-made apparatus. The imported ware was not up to the standard of that made in America. The dilution pipettes, however, were an exception, as certain imported pipettes of this type were the best that have been submitted to the bureau for test.

Eighty-two per cent of all glassware submitted passed the test, and of that tested 90 per cent passed test. This is a very much higher percentage than for any previous year and speaks well for the American manufacturers.

Seventy-eight per cent of the hydrometers submitted passed the test, and of those tested 80 per cent passed test. This also is very much better than the previous year. Of the hydrometers listed as rejected a great number received reports showing the corrections so that the instruments could be used by applying the corrections.

Researches on Density.

Steel (Peffer).—The density of more than 100 samples of steel was determined for the metallurgical division of the bureau in connection with an investigation on volume changes due to different heat treatments.

Zinc (Peffer).—Twenty-one samples of zinc were examined for density, the samples having been prepared under varying conditions as to mechanical working. The report of this was made to the expansivity section and was presented at the New York meeting in April, of the sectional committee on zinc and zinc ores, of the American Zinc Institute and the A. S. T. M. This work is being continued in order to obtain further information to be used in the international standardization of zinc.

Glass (Tool, Peffer).—Thirty-four density determinations have been made on samples of glass to determine the change in density under varying conditions of annealing and heat treatment. This is a joint research being conducted by the divisions of optics and weights and measures.

Sodium chloride (Peffer, Hill).—Further work has been done on the density and thermal expansion of sodium chloride solutions. There remains the task of determining the density of a saturated solution at 60° F. The samples of pure sodium chloride have been prepared by the chemistry division.

Crystals (Peffer, Hill).—Several samples of crystals (quartz, zircon, topaz, etc.) have been examined for density in connection with work being done by the division of mechanics and sound of this bureau.

Denatured alcohol.—Samples of alcohol and denaturants have been obtained and are in the laboratory awaiting the determination of the density and thermal expansion of various denatured alcohols. This work will be done in cooperation with the Bureau of Internal Revenue, Treasury Department, which bureau issues the formulas for the various denatured alcohols. The object of this investigation is to obtain reliable information as to the density and weight per gallon of alcohol when denatured in accordance with the approved formulas.

Visitors.

The section has received visits from many representatives of various manufacturers, who came in the interest of cooperation and in the desire to produce a better grade of apparatus. The results of these conferences show in the increase in the percentage of glassware and hydrometers that passed the test this year in comparison with previous years.

5. GAS-MEASURING INSTRUMENTS.

H. S. Bean.

Research in Connection with Orifice Meters (Bean).

This research embraces a study of the orifice meter as used in the commercial measurement of gas. The principal object of the investigation is to determine the discharge coefficient under all the variable circumstances which may occur within the range of commercial or engineering practice.

In order to solve this problem, it is necessary to make a careful study of the effects of the following variables upon the discharge coefficient: (1) The shape of the orifice, which may vary from a sharp-edged hole in a thin diaphragm to a long flow nozzle; (2) the diameters of the pipe and orifice; that is, the size or area ratio of the pipe and the orifice; (3) the location, size, and finish of the pressure taps; (4) the length of straight pipe on each side of the orifice or the nature of the fittings or obstructions near the orifice; (5) the linear speed through the orifice, or the rate of flow; (6) the absolute pressure in the line and the magnitude of the differential; (7) the density, viscosity, and specific heat of the gas and its deviation from Boyle's law; and (8) steadiness or pulsation of the flow.

Through the courtesy of the War Department, the bureau has been allowed to use in this investigation the large compressors available at Edgewood Arsenal, Edgewood, Md. An experimental pipe line has been installed there, and the set-up as now arranged will permit the study with air of items Nos. 1 to 6, as enumerated above, through a wide range of conditions. It may also be found possible to give special attention to item No. 8. It is hoped that when this work is completed it will be possible to make experiments, using natural gas or other gases for the investigation of item No. 7.

Up to the present time only a few preliminary runs have been made. During these runs approximate checks were made of the discharge coefficients of the flow nozzle which are to be used in the final measurement.

Work of Consumers' Meters Committees (Bean).

In connection with the work of the 1922 consumers' meters committee, a paper on the "Determination of meter capacities" was prepared in conjunction with other members of the committee. This paper formed a part of the committee's report to the American Gas Association and was adopted as the association's standard method for capacity testing of meters. This committee also recommended to the association a uniform method of badging tin-case meters for capacity and size.

The 1923 consumers' meters committee of the American Gas Association has been designated as a committee on the standardization of capacities of consumers' meters. Data have been collected on the different sizes and capacities of meters, particularly of the tin-case type, and much information on the service rendered by meters of different designs has been obtained.

6. THERMAL EXPANSIVITY OF SOLIDS.

W. H. Souder.

Research in Thermal Expansion (Souder, Hidnert, Sweeney).

A research on the effect of mechanical working on the thermal expansion of molybdenum has been completed, and an investigation of the thermal expansion of aluminum alloys is practically completed.

Research in Precision Screws and Graduated Scales (Souder, Harring).

This work is now being carried on in a room set apart and equipped for precision tests. In designing the new dividing engine, the need for which has been previously mentioned, particular attention has been paid to tests of uniformity, especially those made on different types of thrust bearings. Progress has been made in differentiating the effects of the different sources of error, such as periodic and irregular errors of screws, bearing construction and assembly, lubrication films and moving parts, heat treatment for permanence of materials, and the cumulation of errors. This procedure, although somewhat slow as far as shopwork on the actual machine is concerned, has great advantages, since it has eliminated much of the guesswork from uncertain phases of this very important research.

Research in Dental Inlay Technique (Coleman, Souder).

Work on this problem, which was started in January, 1922, has for its purpose the improvement and standardization of dental restoration technique. This work is being conducted under the direction of the bureau by a research associate from a laboratory in New York, N. Y.

Defective dental restorations are responsible for a surprisingly large amount of loss both in money and in health. The defects result from various causes. Among these are defective materials, defective technique (due to carelessness or lack of exact information), and improper selection of materials. Dental literature is filled with conflicting data and offers some extraordinary statements in attempting to explain the chemical and physical phenomena met in carrying out the various techniques.

During the last year the individual materials used, such as plaster, wax, gold alloys, etc., have been studied. The effects of proper and improper manipulations, the magnitude of defects accompanying improper manipulations, and the natural limitations of restorations must be classified before a proper technique can be arranged.

Some of the specific factors met are distortions of wax patterns, distortions of plaster investments upon setting and upon heat treatment, the elimination of the wax pattern, the shrinkage of cast gold, and the elasticity of clasp and wire gold.

So many of these studies have required special equipment that progress on testing has not been rapid until recently. Definite results are being obtained which in many instances show that serious defects are to be expected if the instructions of some so-called experts are followed. Many sets of directions are extremely indefinite, some call for excessive heat treatment of the investments, thus causing misfits; some specify forceful means for elimination of wax; and some use extremely crude methods for casting. Much of the spring gold sold for clasps and orthodontic appliances is of inferior quality. Recent tests show decided improvements in these materials.

Need for New Equipment.

The most urgent need of the expansion laboratory is equipment which will make possible precision determinations of expansion at temperatures up to 1,500° C. This should, if possible, be provided during the next year.

7. WEIGHTS AND MEASURES LAWS ADMINISTRATION.

R. W. Smith.

Enforcement of Federal Standard Barrel Law.

Field investigation (Smith).—A general survey of conditions was conducted in the vicinity of Norfolk, Va., where a large number of barrel factories are located, to determine whether the barrels being manufactured for use in the shipment of farm produce complied with the provisions of the Federal standard barrel law. The division of markets of the State of Virginia had received complaints that short-measure barrels were being manufactured and reported this matter to the bureau for its action thereon. The State authorities also cooperated in the investigation made. Many barrel factories were visited and measurements made upon sample barrels picked at random from stocks on hand. Stave barrels, single and double veneer barrels, and "basket" barrels were included in the survey. It is interesting to note that in only a very few cases were any barrels found to be out of tolerance, that in no case was the discrepancy large, and that in all such cases the capacities of the barrels were in error in excess; that is, they held slightly more than the standard capacity of 7,056 cubic inches, fixed by Federal law.

Tests made at bureau.—Requests are made from time to time for tests on barrels submitted by manufacturers to determine whether or not they comply with the requirements of the Federal standard barrel law. Tests and inspections of such barrels have been made during the course of the year and reports issued to the manufacturers for their guidance.

Investigation of Type and Performance of Commercial Weighing and Measuring Devices (Holbrook, Smith, Roeser).

The studies made incident to this investigation comprise detailed examinations, inspections, and tests upon different types of commercial weighing and measuring devices or of the product of different manufacturers, conducted from the standpoints of construction and performance with a view to establishing the general service which may be expected from any individual samples of the particular group or manufacturer in question. The work serves to demonstrate whether the device is such as to be accurate, reasonably permanent in its indications and adjustment, and not conducive to the perpetration of fraud. Defects in design or construction are disclosed and the manufacturer is often thus enabled to perfect his device so that it will meet official requirements and will render better service in use. These devices are submitted by the manufacturer on his own initiative or at the instance of a State weights and measures official who may in some cases request a report from the bureau in order to assist him in reaching a conclusion as to whether the device in question should be allowed in commercial use in his jurisdiction.

It is a source of regret that the facilities and personnel available for work of this character are so limited that only a very small amount of it may be undertaken. Studies must be limited to those devices presenting new and novel features, and even of these only a small proportion can be examined. Also it is not unusual for several months to elapse following the submission of a device before the examination of it can be commenced. This entire situation is an unfortunate one, since, if the bureau could expand this service to a point where any manufacturer could at any time submit samples of his product for examination and receive a prompt report thereon, an immense amount of assistance could be rendered. The manufacturer would be benefited because he could then perfect his device before it was marketed; the work of the weights and measures official would be greatly expedited because of the superior design and construction of the weighing and measuring devices which he would encounter in the field; and the merchants and the consuming public would profit because the resulting improvement in the instruments used for weighing and measuring would be reflected in greater precision of quantity determination in all transactions by weight or measure.

By reason of the fact that the number of these devices which can be accepted for examination is strictly limited, the bureau finds it necessary strictly to limit the use which may be made of the reports issued thereon. It will be obvious that it would be unfair to permit a manufacturer who happened to have had one of his devices tested to make whatever use he pleased of the report, when another manufacturer, having, perhaps, just as satisfactory a device, could not have his device examined, simply because the bureau had not the funds to carry on the test. It is therefore necessary to make the reports confidential as set forth in the following paragraph which is made a part of all of these reports:

Use of report.—The Bureau of Standards neither approves nor disapproves of commercial weighing or measuring apparatus, and in making tests and

reports such as this one does so for the sole purpose of assisting the manufacturer to a knowledge of the performance of his product and for the information of the bureau. The use of this report or any portion of it, directly or indirectly, in the selling of the product, is hereby specifically forbidden. In no case is the recipient of this report to make any copies or abstracts thereof or to use the subject matter or wording for any advertising purpose whatsoever. This is always made a condition precedent to the test of a device and is repeated here for emphasis and to make it a matter of record, so that there may be no misunderstanding in regard to it.

The examinations of the above nature completed during the past year are as follows:

Gasoline meters	2
"Visible" gasoline-dispensing units.....	2
Piston-type liquid-measuring device.....	1
Liquid-measuring device attachments.....	2
Leather-measuring devices.....	4
Heavy-duty automatic scales.....	2
Platform scale.....	1
Parcel-post scales.....	2
Postal letter scale.....	1
Computing scale.....	1
Butter scale.....	1
Scale-testing device.....	1
Total	20

Federal Legislation Proposed.

It is suggested above that at the present time the investigation of type of commercial apparatus results in advisory reports merely; in other words, there is no legal power in the Federal Government to enforce the recommendations so made. A number of the States, however, practically exercise the power of regulation of type, either directly or through the medium of refusing to seal types which do not meet their approval. This has resulted in nonuniform and in some cases widely divergent requirements. It is apparent that apparatus satisfactory for use in one jurisdiction should be satisfactory for use in all sections of the country, and, if unsatisfactory, it should not be allowed in commercial use anywhere. If standard types of apparatus must be unnecessarily modified to meet the demands of different jurisdictions, a very great economic loss results without any corresponding benefit.

Many manufacturers of weighing and measuring devices have found this condition an irksome one and as a result the Scale and Balance Manufacturers' Association secured the introduction into Congress of a bill designed to secure uniformity of types of weighing and measuring apparatus for commercial purposes throughout the United States for the protection of the general public in their commercial transactions. This purpose is designed to be accomplished by requiring the Bureau of Standards to approve types of commercial apparatus which are found to be accurate, reasonably permanent in their indications and adjustment, and not conducive to the perpetration of fraud, and to allow only such approved types to be imported or to be sold or used for commercial purposes in the United States.

The Annual Conference on Weights and Measures of the United States has repeatedly passed resolutions favoring the principle of this bill. Also many manufacturers of weighing and measuring

devices other than scales have expressed their hearty approval of this principle of regulation and urged that legislation be enacted. This bill was not enacted at the last Congress, but the above association has announced that it will again endeavor to procure legislation along these lines at the coming session.

It is mentioned elsewhere that an increasing number of States are adopting legislation requiring that bread be made and sold only in the form of loaves of certain standardized weights. There has grown up much sentiment in favor of a Federal law putting all interstate commerce shipments of bread on the same basis, with the joint objects of protecting those States having such a law from non-standard weight competition in the case of bread shipped in from outside the borders of these States and of promoting uniformity by establishing a Federal model upon which States not yet having proper bread legislation may in the future base their proposed bills. Recently a Member of Congress requested that the bureau draft a proposed bill along these lines, announcing his intention of introducing it in the next Congress. It may be noted that several years ago in enacting a law regulating sales in the District of Columbia Congress embodied in the law the principle of standard-weight loaves.

The Need for Fundamental Weights and Measures Legislation.

For the past 30 years the weights and measures office of the Coast and Geodetic Survey and (since 1901) the Bureau of Standards have been guided by the so-called "Mendenhall order" in administering the weights and measures laws of the United States. This order accepted the national prototypes of the international meter and kilogram as the fundamental standards of length and mass of the United States, and since 1893 our measures of length and mass in the customary or English system have been derived from these standards in accordance with the law of 1866, by which the use of the metric system was made legal and in which certain equivalents were established.

These metric standards have never been specifically adopted by Congress as the fundamental standards of the United States; nor, in fact, have any other physical standards of weight and measure ever been adopted by Congress except the Troy pound of the mint, which in 1911 was superseded by the "standard Troy pound of the Bureau of Standards," which is derived from the kilogram in accordance with the Mendenhall order and the law of 1866.

Within the past few years it has been held by representatives of the American Institute of Weights and Measures that the official acts of the Coast Survey and the Bureau of Standards in carrying out the Mendenhall order have been without legal sanction, and that the national prototypes of the international meter and kilogram are not, in fact, the fundamental standards of the United States. It is held by the above-named organization that the fundamental standards of Great Britain are also by common law the fundamental standards of the United States. The fact that the standards of Great Britain have several times been changed since 1776, and the further fact that it is now utterly impossible to determine the value of the British yard and pound in use prior to 1776, are entirely overlooked or considered unimportant.

In the case of units of mass no difficulties have arisen, the pounds of the United States and Great Britain being practically identical.

The present legal relation between the British Imperial yard and the meter is slightly different from that established for the United States by the law of 1866, as interpreted by the United States Coast and Geodetic Survey and the Bureau of Standards.

According to the British order in council of 1898,

$$\frac{1 \text{ British Imperial yard}}{1 \text{ meter}} = \frac{3600}{3937.0113}$$

whereas according to the United States law of 1866,

$$\frac{1 \text{ United States yard}}{1 \text{ meter}} = \frac{3600}{3937}$$

This difference, although slight, is sufficient to cause uncertainty and inconvenience in converting from one system of measurement to the other. There is a further complication in the fact that British standards of length are ordinarily intended to have their correct or nominal length when at a temperature of 62° F., while United States standards, especially those used in the industries, are very generally intended to be correct at 68° F.

It has been suggested that the logical and practical method of bringing Great Britain and the United States into harmony in the matter is for both to adopt the simple relation,

$$\begin{aligned} 1 \text{ inch} &= 25.4 \text{ millimeters (exactly)} \\ \text{and } 1 \text{ yard} &= 914.4 \text{ millimeters (exactly)}, \end{aligned}$$

from which would be derived the relation,

$$1 \text{ meter} = 39.370078 \text{ inches (approximately).}$$

This value lies between the present legal values, and somewhat nearer the British than the United States value.

That there would be certain practical advantages in the adoption of the simple relation, 1 inch = 25.4 millimeters, is admitted both by those who favor the use of the metric system and by those who oppose it. For example, in addition to the advantage of bringing Great Britain and the United States into agreement, the suggested change would make legal the relation that is already widely used in both England and America in screw cutting and similar work where it is desired to turn out a product in one system of measurement on a machine manufactured in accordance with the other system.

The arguments in favor of enacting legislation specifically adopting our metric standards as fundamental may be briefly summarized as follows: (1) It would put on a definite legal basis the standards that have been in use for the past 30 years. (2) They are the best physical standards available from the standpoint of permanency and accuracy. (3) If supplemented by a statement of the exact relation between the units of the metric and the customary system, the fundamental standards would continue to serve as the basis of both systems of units.

An objection to proposing this legislation is the danger that it will be misinterpreted as an attempt to force upon the United States the exclusive use of the metric system.

Compulsory metric legislation is considered by this bureau to be inadvisable, and the above suggested action should in no sense be so interpreted. It should be interpreted solely as an attempt to put our weights and measures on a definite legal basis and in the end to bring about uniformity with Great Britain.

It should be borne in mind that the specific adoption of the national prototype meter and kilogram as the fundamental standards of length and mass of the United States, together with the adoption of definite relations between the customary and metric units would not in itself bring about complete uniformity with Great Britain. Similar action on the part of Great Britain would be necessary.

In case Great Britain should continue to regard the Imperial yard and pound as the fundamental standards and to derive the metric units therefrom in accordance with the new relation, there would still be a slight theoretical difference. This difference, however, would be insignificant, being in the case of the yard about one-third of the present difference.

Annual Conference on Weights and Measures.

The Annual Conference of the Weights and Measures officials of the United States, held at the Bureau of Standards, is one of the most important means through which the bureau extends its cooperation with State and local departments of weights and measures and fosters uniformity in weights and measures laws, rules and regulations, methods of inspection of apparatus, etc., and the efficient administration of weights and measures departments throughout the United States. The conference has always been sponsored by the bureau and has grown from a group of five officials, who met in 1905 to discuss common problems, to an organization national in its scope, embracing in its membership weights and measures officials from all parts of the country. Its meetings are attended, in addition to the officials, by representatives of manufacturers, weighing departments, railroads, and industries. Its sessions are devoted to a study of all of the problems of weights and measures administration, such as model laws, specifications and tolerances for weighing and measuring instruments, methods of testing commercial apparatus, newly developed devices, testing equipment, organization and conduct of departments, methods of carrying on supervisory activities, special surveys, etc. Papers are presented on technical subjects by those with special experience, reports are made of investigations and surveys conducted by the bureau and by the various States and cities, and many problems of current importance are brought up for discussion and solution by those in attendance.

The sixteenth annual conference held this year was eminently successful in every way. The formal actions of the conference included the adoption of tolerances for heavy-duty automatic scales and the tentative adoption of specifications and tolerances for fabric-measuring devices and for vehicle tanks used as measures in the sale of gasoline, fuel oil, and similar products. While the actions of the conference have no legal status, its conclusions are generally accepted as authoritative and are given effect by promulgation by the proper authorities in most of the jurisdictions having weights and measures departments.

Acting through the conference, the bureau has been able to accomplish much in encouraging officials to an efficient and enthusiastic administration of their offices, and the considerable degree of uniformity that now prevails throughout the United States may largely be attributed to this activity.

The report of the conference, which is published each year in printed form, is a verbatim report of the meetings. These reports constitute a valuable source of weights and measures information, containing as they do many technical papers, specifications, and tolerances for weighing and measuring apparatus and, what is probably of equal importance, the discussions on these matters and on the practical problems of the weights and measures official.

State Conferences.

In addition to the annual weights and measures conference held at the bureau, meetings of the State, county, and city weights and measures officials are held annually in many States. These meetings are attended by a much larger group of local officials than are able to attend the national conference, and their programs are concerned not only with problems national in their scope, but also with additional problems arising as a result of local laws and conditions. As a result these meetings offer a splendid opportunity for advising these officials as to how problems similar to those confronting them are being handled elsewhere and otherwise furnishing assistance. Consequently, the bureau always makes an effort to have a representative present. Last year State meetings of this character were attended in Michigan, Minnesota, Wisconsin, Indiana, Massachusetts, Pennsylvania, and New Jersey.

State Weights and Measures Laws (Parry).

Much work was done during the year in bringing up to date the compilation of State laws in relation to weights and measures. There is considerable legislation of this character enacted every year throughout the country, and in order to keep the files of the bureau current in this respect new codes of laws must be carefully checked for new enactments and all new compilations of laws examined for any changes made in wording or in the reference numbers of the old sections; consideration must then be given to the question as to what portions of former laws have been repealed, and all this material must be transcribed for permanent record.

Although the edition of the bureau's former publication on these laws, dated 1912, is now entirely exhausted and the material is obsolete on account of the radical nature of the changes made in the laws of a very large number of States, lack of funds in the last few years has precluded the possibility of having a new edition printed. Notwithstanding this it is very necessary that an up-to-date file be kept at the bureau, since this is found necessary in answering a large number of inquiries received from various sources.

Among the States recently enacting new weights and measures legislation may be mentioned Connecticut, which adopted new requirements concerning the sale of coal by weight and a new bread statute; Indiana, which fixed standards for certain shipping containers; Massachusetts, which abolished its list of bushel weights and required that all fruits, nuts, vegetables, and grains, except berries

and commodities in original standard containers, be sold at retail by weight or numerical count, further regulated the manner of sale of coal and coke, and made several other changes in their code; Nevada, which adopted a public weighmaster law and further standardized containers; Rhode Island, which passed an act in relation to liquid-measuring devices; New York, which amended its law in relation to the marking of the net contents on containers; Pennsylvania, which made some changes in its list of weights per bushel, thus bringing it more nearly into agreement with those of other States; South Carolina, which adopted a new general code; West Virginia, which made changes in their weights per bushel list; and Illinois, North Dakota, Washington, and Wisconsin, all of which passed new bread legislation requiring that all bread be sold in standard size loaves only. The last-mentioned method of sale of bread is making rapid headway throughout the country. Some 12 States now require that bread be sold in this manner, the majority of these laws having been adopted recently. The Annual Conference on Weights and Measures has, as before mentioned, several times gone on record as being very strongly in favor of this method of sale and has adopted a model law on this subject with which most of the laws mentioned above are in substantial agreement.

Investigations.

During the year a number of investigations have been made in cooperation with various agencies, and five of these, which illustrate well the scope of the work of cooperation carried on, may be especially mentioned. One of these investigations was made at the request of the Annual Conference on Weights and Measures, one as a result of a conference with manufacturers, one at the request of a State department, and the others at the request of other Federal departments.

Tolerances for bread (Holbrook, Smith).—The committee on specifications and tolerances of the Annual Conference on Weights and Measures was engaged during the year in a study of tolerances for loaves of bread. Two questions are of vital importance in determining suitable tolerances, namely, the variations between individual loaves when manufactured in accordance with good commercial practice and the shrinkage to be expected between the time of baking and the time the bread becomes stale. In the absence of sufficient data on these factors, the bureau was called upon to procure information in this connection. Since it is the earnest desire of the bureau to further the adoption of proper and uniform tolerances throughout the United States to be used in the enforcement of weights and measures laws, an investigation was accordingly made in Washington, D. C. In the course of this investigation the individual weights of 2,613 loaves of bread of various kinds and manufactured by a number of bakeries were determined, and the results plotted in such a form as to reveal the mean weight and deviations from mean weight for each group. Shrinkage curves were also prepared for various sizes and kinds of loaves, following a study of the behavior of individual weights of a representative number of loaves of each size and kind kept under known conditions of temperature and humidity.

Commercial filling of milk and cream bottles (Holbrook, Peffer, Smith).—An investigation to determine the average point to which bottles of milk and cream are filled under good commercial filling conditions was made as a result of a conference with the manufacturers of milk bottles who are seeking a uniform requirement throughout the United States as to the point on a bottle defining its capacity. In some States this point is established by law or regulation as the cap seat while in other States this point is fixed as one-eighth or one-quarter inch below the cap seat. The latter requirement was recommended by the bureau some years ago, and this investigation was made to determine whether any change in this recommendation was indicated by present conditions. This question is of general importance to the milk-bottle industry, since, if a uniform requirement is adopted, it will reduce the number of sizes to be produced with a consequent economy resulting from a decrease in number of molds, stocks required to be carried, etc., and to the consuming public since, if the designated filling point is higher than the point to which the bottles can be filled under commercial conditions, short measure in the sale of milk and cream inevitably results. The investigation was carried on in the cities of Chicago, Philadelphia, New York, and Washington, conditions in these cities being considered as representative of the country at large. A total number of 3,610 bottles, representing the product of 46 different dairies, were examined, and the results fully confirmed the correctness of the bureau's former recommendation. These results will be presented to the milk distributors and their cooperation sought in the procuring of a proper and uniform standard.

In the course of this investigation there was developed a method of readily determining in the field the height to which bottles of milk and cream are filled, involving only the use of a simple special gauge which is applied to the outside of the bottles without disturbing the bottle cap. This will be of considerable assistance to weights and measures officials in the course of their check-up activities in their respective jurisdictions. There was also developed in this connection a method for testing milk and cream bottles for accuracy. For this use special types of adjustable depth gauge and bulb burette were designed, the first for the purpose of establishing at any desired point below the cap seat the level of the liquid used in testing the bottles, and the second for rapidly and accurately determining the errors of the bottles under test.

Leather-measuring machines (Roeser).—During the past year extensive tests were made of machinery for measuring leather in plants in the vicinity of Boston, at the request of the Massachusetts weights and measures department. One other test was made for the Board of Trade representing New York City manufacturers. Investigations have been made to determine suitable material from which to make standard test sheets and the proper form of these test sheets.

Spring balances (Holbrook, Roeser).—An investigation of spring balances has been carried on during the year at the request of the Coast and Geodetic Survey to determine the most suitable type of balance to be used in stretching tapes in base-line surveys. The

investigation involved a study of the uncertainty to be anticipated in the use of the types at present employed and of the changes in the elasticity of the springs under varying conditions of temperature.

Household measuring cups (Smith).—An investigation on household measuring cups conducted at the request of, and in cooperation with, the Bureau of Home Economics of the Department of Agriculture has been almost completed. It was believed by the Bureau of Home Economics that many of the measuring cups on the market were in error, and the assistance of this bureau was requested to determine the actual conditions existing.

The investigation embraced 48 cups, secured from 33 different manufacturers, each of these cups being tested at capacity and at its various graduated subdivisions. The need for some effort toward improving the accuracy of cups was thoroughly established, since errors in excess of 25 per cent were not uncommon. In addition, it was found that there was no uniformity in the character of graduations, markings, etc. At the request of the Bureau of Home Economics a code of specifications and tolerances designed to make available a satisfactory measuring cup for use in cooking has been prepared and submitted to the various manufacturers for their comments and suggestions.

Foreign Weights and Measures (Parry).

The bureau has many requests, especially from American manufacturers of weighing and measuring equipment, to furnish information in relation to foreign weights and measures, and the bureau feels that these data should be furnished whenever possible. Consequently, a file, as nearly complete as possible, is being assembled, and progress has been made toward this goal during the year. As a result it has been found possible to supply this information to persons requesting it in greater detail than previously.

Legal Weights per Bushel.

The bureau is strongly of the opinion that the best method of sale for dry commodities is by weight without reference to weights per unit of volume, and that the arbitrary and conflicting bushel weights established by State statutes might better be entirely discarded in favor of the hundred weight unit. Nevertheless, on account of the steady demand by growers, shippers, and other interested parties for information as to the legal bushel weights in the various States, it is deemed advisable to replenish as soon as possible the supply of Circular No. 10, Legal Weights (in pounds) per Bushel of Various Commodities, which is now entirely exhausted. Accordingly, this circular has been revised and brought up to date and will be ready for printing in July.

Miscellaneous Activities (Holbrook, Smith, Roeser).

The routine activities of the section comprise a large amount of correspondence, many personal interviews, the preparations for the Annual Conference on Weights and Measures, and the preparation of the conference report. Much of this correspondence is from weights and measures officials, from manufacturers of weighing and measuring devices, and from other commercial concerns, and relates

to specifications and tolerances, laws, regulations, special weighing or measuring problems, and the like. Many inquiries along similar lines are also received from private citizens, frequently accompanied by requests for assistance from the Federal Government in correcting some local short weight or measure condition or in proceeding against some alleged violator of State or local law. Such requests must, of course, be referred to the State or local officials, since the bureau is not empowered to handle matters of this kind, except in the case of standard barrels or lime barrels. Personal interviews with officials, representatives of manufacturers, and inventors and designers of new weighing or measuring devices follow the same lines as mentioned above.

During the year attention has been given to the following: The drafting of a number of bills on weights and measures subjects for introduction into the Federal Congress or into State legislatures, this work being done in each instance at the request of properly interested parties, such as Members of Congress, State officers, etc., the preparation, at the request of the Post Office Department, of tolerances for scales used in the Postal Service, the marking of length intervals on a number of strips of material to be used by the District of Columbia department of weights and measures in testing fabric-measuring devices, the assembly of a set of standard weights and measures presented to the Government of the Virgin Islands, and attendance at various conferences held at the bureau and elsewhere at which matters related to weights and measures were discussed.

8. INVESTIGATIONS AND TESTS ON COMMERCIAL SCALES AND RELATED WORK.

H. M. Roeser.

Investigation of Railroad Track Scales (Holbrook, Roeser, Fell, Enwright, Rawson, Edwards, Giessemann, Hancock).

Excellent progress has been made during the past year in the investigation of the condition of railroad track scales throughout the country. As has been the regular experience in the past few years, however, it was again found impossible to keep the track-scale testing equipments in the field during the entire year on account of lack of funds. This year time lost through the necessity of laying up equipments from this cause approximated one-third of the time of all the equipments. Part of this time was utilized in necessary overhauling and repairing of the equipments, and, by transferring men from track scale to mine scale equipments and granting one inspector six months' leave without pay efficient employment of the field force was found possible.

In spite of the delays mentioned above the railroad master scale testing schedules were completed in regular order, involving the test of 19 master scales; also 636 commercial railroad track scales were tested by the three equipments. The field personnel remained intact with the exception of the six months' period of leave by one inspector mentioned above.

The men comprising the inspection staff in this service have been trained especially for it, and the smoothness and efficiency which characterize their efforts in maintaining a good record of work accomplished in the face of serious handicaps reflect the results of this training as well as a commendable spirit of fidelity to duty.

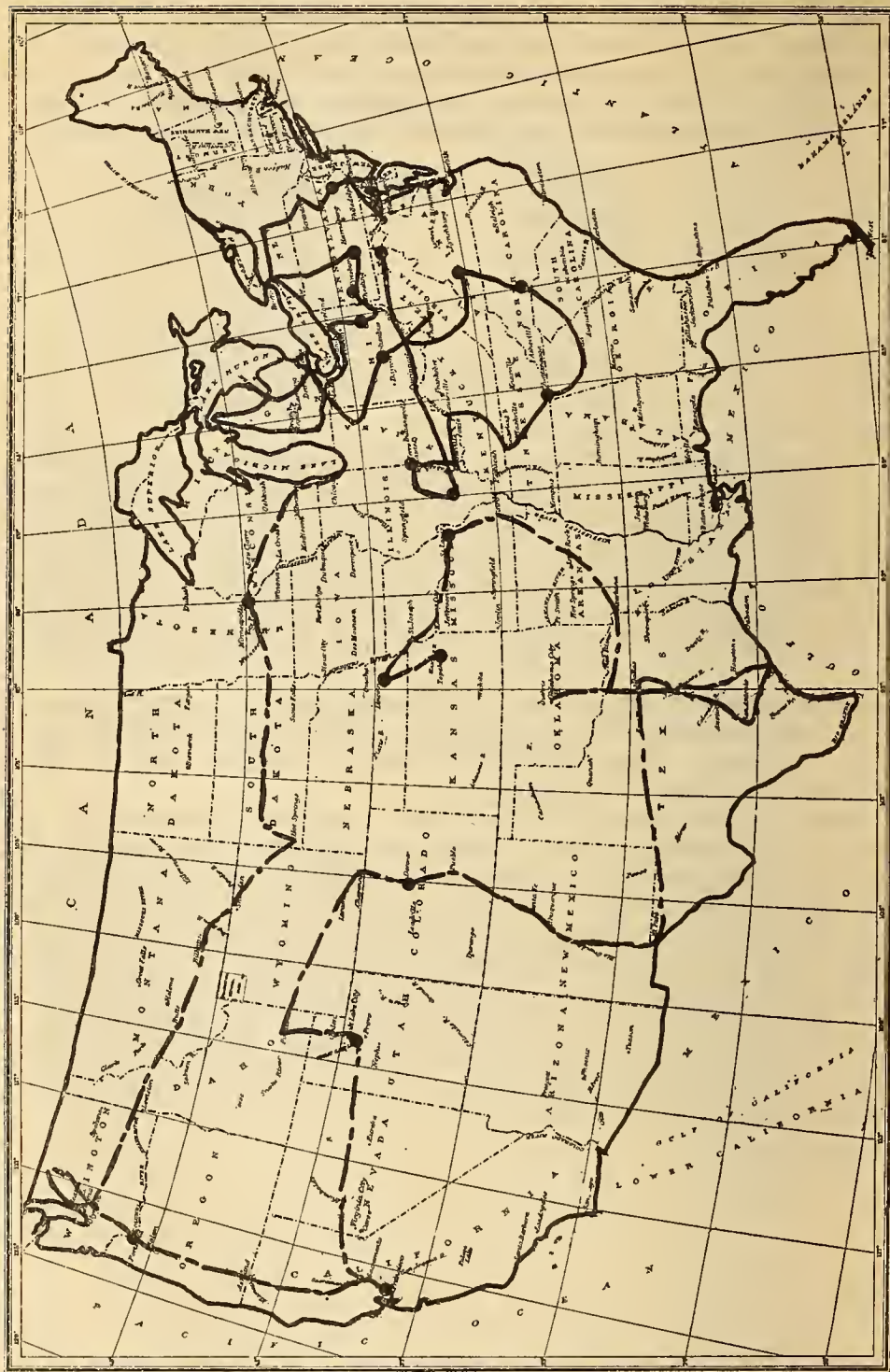
The work was well distributed throughout the country. Tests were made in 34 States and the District of Columbia, as follows:

Arkansas.	Maryland.	Oregon.
California.	Michigan.	Pennsylvania.
Colorado.	Minnesota.	South Dakota.
Delaware.	Missouri.	Tennessee.
District of Columbia.	Montana.	Texas.
Georgia.	Nebraska.	Utah.
Idaho.	New Jersey.	Virginia.
Illinois.	New Mexico.	Washington.
Indiana.	New York.	West Virginia.
Kansas.	North Carolina.	Wisconsin.
Kentucky.	Ohio.	Wyoming.
Louisiana.	Oklahoma.	

The accompanying map shows the routes followed by the two master scale testing equipments and also the location of railroad master scales throughout the country. These two equipments are designated as No. 1 and No. 2. The No. 3 equipment is especially designed for ordinary commercial track-scale testing, and since being put into operation last January has operated in Pennsylvania, Maryland, District of Columbia, Virginia, Delaware, and New Jersey.

As is the usual custom, the work has been planned to make the results as representative as possible by distributing tests among numerous owners. Tests were made on 78 railroads and at approximately 160 industrial plants.

A résumé of the results of the tests of railroad track scales is shown in the following table. This does not show the results of master-scale tests, which are presented elsewhere. For the purpose of bringing out certain facts of interest the data have been arranged geographically, the country being divided into three districts in accordance with the territorial subdivisions adopted by the Interstate Commerce Commission in its "Report on the statistics of railways," which are designated the Eastern, Southern, and Western districts. The results are classified to indicate ownership by railroads, industries, and Federal Government. A brief analysis of the errors on incorrect scales is also given.



Map showing territory served by Bureau of Standards track scale testing equipment for the fiscal year 1923.

Solid line, route of equipment No. 1. Dot-and-dash line, route of equipment No. 2. Dotted line, route of equipment No. 3. Heavy dots, location of master scales.

RESULTS OF TESTS ON TRACK SCALES.

District and scales owned by—	Number of scales.	Passed tolerance.		Failed tolerance.		Mean numerical error in per cent.	Analysis of errors on incorrect scales.					
		Number.	Per cent.	Number.	Per cent.		Scales weighing heavy.			Scales weighing light.		
							Number of scales	Per cent of incorrect scales.	Mean plus error in per cent.	Number of scales.	Per cent of incorrect scales.	Mean minus error in per cent.
Eastern:												
Railroad.....	205	94	45.8	111	54.2	0.43	58	52.2	0.52	53	47.8	0.87
Industrial.....	87	42	48.3	45	51.7	.40	16	35.6	.41	29	64.4	.80
Government.....	9	6	66.7	3	33.3	.39	.....	.....	.....	3	100.0	.96
Total.....	301	142	47.2	159	52.8	.42	74	46.5	.49	85	53.5	.85
Southern:												
Railroad.....	87	34	39.1	53	60.9	.45	23	43.4	.41	30	56.6	.83
Industrial.....	13	4	30.8	9	69.2	.26	5	55.6	.30	4	44.4	.28
Government.....	3	.....	.0	3	100.0	.50	2	66.7	.65	1	33.3	.21
Total.....	103	38	36.9	65	63.1	.43	30	46.2	.41	35	53.8	.75
Western:												
Railroad.....	157	105	66.9	52	33.1	.30	31	59.6	.46	21	40.4	1.01
Industrial.....	73	43	58.9	30	41.1	.29	18	60.0	.43	12	40.0	.72
Government.....	2	.....	.0	2	100.0	2.84	1	50.0	.24	1	50.0	5.44
Total.....	232	148	63.8	84	36.2	.32	50	59.5	.45	34	40.5	1.04
All districts:												
Railroad.....	449	233	51.9	216	48.1	.39	112	51.8	.48	104	48.2	.90
Industrial.....	173	89	51.4	84	48.6	.35	39	46.4	.40	45	53.6	.74
Government.....	14	6	42.9	8	57.1	.76	3	37.5	.51	5	62.5	2.84
Total.....	636	328	51.6	308	48.4	.38	154	50.0	.45	154	50.0	.87

The above table shows that 51.6 per cent of the railroad track scales tested were within the tolerance prescribed for good performance, namely, 0.20 per cent of the applied load, or 200 pounds per 100,000 pounds of applied load. By geographical subdivisions it is found that 63.8 per cent of the scales in the Western district, 47.2 per cent in the Eastern district, and 36.9 per cent in the Southern district passed the tolerance. The mean errors of the scales in these districts are 0.32 per cent in the Western district, and 0.42 per cent and 0.43 per cent in the Eastern and Southern districts, respectively. With regard to the incorrect scales tested, the number weighing heavy and the number weighing light are equal, although the mean errors in the latter case are considerably larger. The tabulated figures for this case do not reflect with entire accuracy general conditions, owing to the fact that large negative errors are generally found in the comparatively few instances where interference with the performance of the scale is found to be due to obstructions to the weighing mechanism, and these few large errors affect the mean results to a rather immoderate extent.

The tabulation seems to indicate that the advances in accuracy in railroad track scale performance noted in recent years are being well maintained. The percentage of scales passing the tolerance, namely, 51.6 per cent, is higher than last year, when the figure was 48.5 per cent, and higher than any previous year, with the exception of 1921. In the Southern district the percentage of scales passing

the tolerance is very materially improved, some improvement is noted in the Western district, while in the East the percentage has slightly decreased. This figure of 51.6 per cent representing all the scales tested follows a gradual increase in the quality of performance since the work was begun in 1914, when the percentage of scales passing the tolerance was 38.2.

The value of this service in promoting better weighing conditions is strikingly presented by the conditions found in the Western district. In the United States there are about 4,150 railroad-owned track scales, of which number 33 per cent are in the Western district. Conditions governing the handling of the master-scale schedules usually make it necessary and advisable for the bureau to do a larger proportional amount of its work in that district than in the others, and most of this is on railroad-owned scales along more or less well-defined routes, which by force of circumstances must be covered each year. This results in localized intimate contact with weighing conditions, and it will be noted in the above table that 63.8 per cent of the railroad-owned scales in that district passed the tolerance on good performance as compared to 44.6 per cent, the figure obtained by combining the other two districts. It is thus evident that the general conditions of weighing freight might be vastly improved if the bureau's facilities for handling this class of work were extended.

During the past year corrective adjustments were made on 40 track scales. This service is extended to owners whenever the condition of their scales justifies it and when it can be done without loss of time which could be utilized in making other tests.

Calibration of Privately-Owned Test Cars.

During the past year 16 test cars belonging to railroads were calibrated. This service is extremely important, in that it assures a correct standard to the owners in maintaining their own weighing equipment.

Calibration of Master Scales.

Two new master scales were put into service and tested for the first time by the bureau last year. The total number in the United States is now 19. These were all tested in regular order, and practically all were found to be in good weighing condition and receiving a commendable amount of attention to maintenance. The bureau has noted a growing sense of responsibility among owners toward the proper maintenance of these scales which are used as a control for the 10,500 railroad track scales in the United States. The annual testing and adjustment of these scales is considered by the bureau to be its most important and responsible work in this field, and it is, in fact, the fundamental control of all revenue freight weighed in the country.

Bureau of Standards Master Scale.

In connection with the subject of master scales and test cars used by railroads and industries attention must again be called to the fact that the Government master scale purchased some years ago is still in storage. Funds should be provided for the purchase of a proper site and for the erection of a building to house this scale, so that the bureau could put it to the use for which it is intended.

Until this scale can be installed for use the Government can not realize upon its investment, its scale work can not be made of maximum efficiency, and the service which the bureau should render must necessarily be greatly curtailed.

As pointed out last year, this scale was contracted for in 1916, it being much needed even at that time, and it was intended to house it in a centrally located test depot. As mentioned above, this has not yet been done, although since that time the bureau's track-scale work has broadened in scope and the need has consequently become more urgent. Track-scale testing equipment No. 3, contemplated at the time of the purchase of the scale and put into service at a more recent date, comprises test cars Nos. 3 and 4, these being 40,000 and 80,000 pound self-contained test units traveling on their own wheels. Therefore, they must be reweighed at intervals not exceeding two months in order to maintain and assure their accuracy, and this reweighing should be done on a scale operated and guaranteed by the bureau. Moreover, the 160,000 pounds of test weights (including the special trucks) carried on equipments Nos. 1 and 2, which are used in certifying to the accuracy of every master scale in the United States, must be repainted and adjusted from time to time and the equipments overhauled. The bureau has no present facilities for doing work of this character.

In addition to the needs of the bureau the proposed testing station would also be used for standardization of the test cars of all railroads in the locality in which the scale is located and the calibration of weights carried thereon, as well as the calibration of all heavy weights submitted for test by industries or railroads located in the vicinity. The maintenance of a Government-owned master scale and testing depot at some central point would do more, perhaps, than any other thing to furnish a correct standard of weight to be transferred to railroad-owned and industrial scales, to quicken the appreciation of accurate weights and weighing, and to reduce claims, allay suspicions, and provide a more stable basis for all business carried on by weight.

In the opinion of the bureau the city of Chicago is the most favorable situation in the country for the station. This location, being a central one, would most efficiently be reached by the bureau's several equipments, and it also would enable the bureau to serve a maximum number of railroads and industries.

Track Scales for Weighing Grain.

Interstate Commerce Commission Docket 9009 (56 I. C. C. 347), decided January 13, 1920, and American Railway Association Grain Circular No. 1, effective January, 1921, published pursuant to the recommendations in the above-mentioned decision, carry specifications for track scales for weighing grain and require among other things that scales of this character shall comply with a tolerance of 0.10 per cent of the applied load as compared to a tolerance of 0.20 per cent for track scales other than grain scales. Incidental to its regular work in testing track scales, the bureau last year tested 32 track scales used exclusively for weighing grain, and of this number the performance of only two was found to be within the prescribed tolerance. The mean error of the group of scales was 0.40 per cent. This degree of inaccuracy is a serious condition, and one which is

a fruitful source of complaint among the handlers of grain. Unfortunately, with existing facilities, the bureau is unable to correct this state of affairs as rapidly as the condition warrants.

Cooperation with Outside Agencies (Roeser).

During the past year the bureau has maintained representation on a committee of the American Railway Engineering Association, which completed specifications for the manufacture and installation of motor truck, built-in, self-contained, and portable scales for railroad service.

Bureau of Standards Letter Circular 88, The Performance of Railroad Track Scales, which gives results of tests of 1,000 track scales, arranged in such a manner as to show the effect of current tolerances on the grading of track-scale performance, was issued last February and has been widely circulated in response to an active demand. These tolerances are to receive the attention of the above-mentioned committee during the current year. Specifications and tolerances for heavy-duty automatic scales will also be considered.

Investigation of Mine Scales (Holbrook, Roeser, Fell, Rawson, Edwards, Giessemann, Hancock).

The investigation of the condition and accuracy of scales used at coal mines in determining the amount of coal loaded by individual miners from which wages due are computed was very seriously hampered in the last 12 months on account of the strike in the union fields. Conditions during the summer and fall were such that it appeared that no good purpose would be subserved by attempting to carry on the work, and consequently no effort was made to get the equipments into the field until the spring. As a result it was found possible to save a considerable portion of this fund, and at the close of the fiscal year there was an unexpended balance of approximately \$5,000 for return to the Treasury. Since the work has been resumed it has been progressing in the fields in the vicinity of Clarksburg and Fairmont, W. Va., in southern Indiana and Illinois, and in Pennsylvania. The work has been handicapped to some extent due to unavailability of suitably trained men. The duties are rather arduous, and men with the degree of physical ability and technical training required are difficult to obtain and to hold in this service.

Specifications covering suitable types of weighing equipment and methods of installation for the above service have been prepared. These have not yet been published, as recent developments in work in this field indicate the advisability of some revision of these specifications and confirmation of some of the technical details from independent sources.

In connection with its investigation of mine scales the bureau has in a number of instances been confronted with the fact that there is an unexplained discrepancy between total weight of coal mined as determined on tippie scales for the purpose of determining the wages due the miners and the corresponding weight as determined shortly thereafter on railroad track scales for the purposes of freight charges and invoicing. This discrepancy is a matter of very considerable importance, and therefore a foundation has been laid for an investigation by the bureau in cooperation with interested

parties to determine the underlying causes for this condition. The bureau is in an excellent position to gather the necessary data, since its mine-scale and track-scale testing equipments can be used in conjunction in the pursuance of the investigation.

Conveyor Weighers (Roeser).

Attention has been given to machinery used to weigh a continuous stream of material such as coal, crushed stone, etc. Examinations and tests have been made at two plants and literature collected covering this type of weigher. The bureau anticipates considerable demand for attention to this type of weighing equipment. Facilities for meeting the demand should be provided, as this class of weighing is an important one and is gradually increasing, particularly in the mining industry and at stone and coal handling plants.

9. GAUGE STANDARDIZATION.

D. R. Miller.

Development and Construction of Apparatus and Gauges.

Alterations in projection lantern (Miller, Carter).—During the year the projection lantern used in the measurement of gauges has been altered so that the angle of thread gauges can be measured with the optical system arranged in two ways: (1) With the optical axis of the projection lens system perpendicular to the axis of the thread, and (2) with the optical axis parallel with the helix angle of the thread.

Arrangement (1) is the usual arrangement and is employed in all lanterns heretofore developed at the bureau and, so far as is known, in England at the National Physical Laboratory. Arrangement (2) is employed in a lantern developed by the Bausch & Lomb Optical Co. The two arrangements give different readings for the angle of thread when the helix angle is large. Preliminary tests and theoretical considerations indicate that the readings by both methods are approximations. It is proposed to make up threads of various helix angles to be measured by both methods to determine if it is necessary to apply corrections to the readings for either method to obtain the true angle of thread. This work will be of considerable interest to gauge and thread-cutting toolmakers who use the projection lantern for measuring angle of thread.

Dial micrometers (Miller).—In connection with the study of dial micrometers for measuring the thickness of paper it is necessary to devise means for measuring the contact pressure of the instruments. Where the instruments are reversible, the force necessary to move the mechanism in both directions was measured by means of an even arm balance and weights. To measure the contact pressure of instruments that were not reversible, the instruments were allowed to strike the end of a flexible cantilever beam and the deflection noted. The beam was then calibrated to determine the weight necessary to cause the same deflection.

Penetration needles for testing bituminous materials (Haven).—During the year the section was requested to check the dimensions of penetration needles used in the testing of bituminous materials. The dimensions of these needles were specified by a committee of the American Society for Testing Materials. A special fixture was

made to facilitate the measurement of the flat at the point and the angle of point. In this fixture the needle was held vertically with the point resting on a flat surface and measurement was made over wires by means of a micrometer caliper placed at various known heights from the point. The diameter and angles can be computed from the micrometer measurements and the known diameter of the wires.

Manufacture of precision gauge blocks.—The work of manufacturing precision gauge blocks was continued during the year. This work was carried on in the shop when the force was not engaged in more urgent work. The work of making 34 sizes of metric blocks, 20 blocks of each size, is now about 60 per cent completed.

Standardization of Stock Sizes and Dimensions (Miller, Fullmer).

One of the most useful functions of the section has been in the collection of data of stock sizes, standard dimensions, and tolerances for common metal shapes and machine elements. Two letter circulars were published along this line, one Letter Circular No. 24, Standard Thickness of Sheet Metal, was very favorably received and, judging from the number of requests for the circular, it supplied information that was not readily available and was very much desired in industry. The other publication, Letter Circular No. 18, Important European Screw Thread Systems and Dimensions of Bolt and Screw Heads and Nuts, is of interest to manufacturers and exporters and to manufacturers making machines for export intended to interchange with screw thread systems employed in various European countries.

Cooperation with Engineering Societies and the National Screw Thread Commission.

Considerable time was spent during the year in doing cooperative work with the various engineering committees and commissions engaged in standardizing sizes of and tolerances for machine elements. Tables for tolerances for various classes of fit for use in the progress report of the plain gauge committee were recomputed during the year. Brass screws with nuts made to the "across flat" dimensions corresponding to the standard of the Society of Automotive Engineers were made up and submitted to tensile test to determine whether brass nuts of these dimensions were stronger than the bolt upon which they were fitted. This work was done for the information of the National Screw Thread Commission to determine whether the S. A. E. dimensions across flat on nuts were suitable for soft materials as well as for the grades of steel ordinarily used. Circulars published during the year for the information of or in cooperation with the National Screw Thread Commission are listed with the other publications of the division.

Researches.

Gauge steel investigation (Miller, Laughlin).—The gauge section, in cooperation with the metallurgical division, has carried on an extensive investigation of steels suitable for use for gauges. The part the gauge section has taken in the investigation has been mainly in the measurement of specimens before and after annealing, hardening, and tempering to determine the dimensional changes that occur; also a number of the specimens are being measured

from time to time to determine seasonal changes. In connection with this investigation, 2,185 specimens have been measured and 450 specimens have been ground or otherwise machined. The results obtained are reported in nine progress reports of the gauge steel committee.

Strength and tightness of threaded joints (Miller, Fullmer).—Investigation of the effect of errors in thread form, lead, and taper on the tightness and strength of threaded pipe joints has been continued during the year. In this investigation it was found that there were slight differences in either tightness or strength of straight and taper couplings on taper pipe. It is usually considered that the tapered coupling when used with tapered pipe makes a stronger and tighter joint than the straight coupling, and the report on this investigation has been held up until further tests can be made to check the results already obtained on this point.

Material for gauges.—In cooperation with the manufacturers of stellite and a number of users of gauges an investigation has been carried on to determine the suitability of stellite as material for gauges. A number of stellite gauges were made to the drawings furnished by the users and the gauges used by them in actual inspection in comparison with steel gauges. Reports have been received from all of the users, and these reports show that stellite wears from four to six times as long as the usual hardened steel gauge. Some stellite disks have also been received to be compared with hardened steel disks on a wear-testing machine.

Research on development of millionth comparator (Miller, Haven).—Some work has been done on the construction of a satisfactory ultramicroscope or millionth comparator. Such a comparator is desired to check the results of the present methods of comparing and determining the parallelism of precision gauge blocks by light interference. Interference methods for determining the absolute thickness of these blocks and for determining the planeness of surfaces are entirely satisfactory, and there is no occasion for a change of methods. It is felt, however, that a contact method of comparing blocks and determining parallelism of surfaces would serve as a check on these methods. The comparator employing an optical lever system and somewhat similar to the comparator used at the National Physical Laboratory was tried out. It was found that with the particular arrangement used the contact pressure varied considerably for small differences in the length of blocks. Recently some experiments have been made with the use of condenser plates in the plate circuit of an oscillating audion tube, and this arrangement gives indications of being successful.

The section has cooperated with engineering committees and commissions, such as the American Engineering Standards sectional committees on plain limit gauges and screw threads, the gauge steel committee, and the National Screw Thread Commission, in the standardization of sizes and tolerances of screw threads, bolts and nuts, and machine elements. The following communications have been prepared for the National Screw Thread Commission: No. 42, Strength of brass bolts and nuts; No. 45, Compilation of replies to letters regarding allowances and tolerances on wrench jaws; No. 47, Screw threads in the electrical industry (re-

vised); No. 49, National fire-hose thread revised to national hose thread form; No. 50, Questionnaire on well casing and casing threads.

PUBLICATIONS.

The following papers relating to the work of the division of weights and measures were either issued or ready for press at the close of the year:

A study of commercial dial micrometers for measuring the thickness of paper (Paul L. Houston and D. R. Miller), Tech. Paper No. 226.
 The effect of mechanical working and heat treatment on the structure and the thermal expansion of molybdenum (Peter Hidnert and W. B. Gero, the latter of the Westinghouse lamp laboratory), Sci. Paper (in press).
 The testing of hydrometers, Circular No. 16 (revision).
 Invar and related nickel steels, Circular No. 58 (revision).
 Gas-measuring instruments, their operation, methods of testing, and their use, Circular (ready for printing).
 Report of fifteenth annual conference on weights and measures, Miscellaneous No. 51.

The following mimeographed letter circulars have been issued:

No. 5. Liquid conversion tables.
 No. 18. Important European screw thread systems and dimensions of bolt and screw heads and nuts.
 No. 24. Standard thicknesses of sheet metal.
 No. 72. Sieve-testing apparatus.
 No. 74. Standard specifications for sieves.
 No. 88. The performance of railroad track scales.
 No. 89. Conversion tables for petroleum oils.
 No. 91. Fitting of plugs for class B weights.
 No. 95. United States petroleum oil tables.
 No. 96. Specific gravity and weight per gallon of milk and cream.

The following communications have been prepared in mimeograph form for the National Screw Thread Commission:

No. 42. Strength of brass bolts and nuts.
 No. 45. Compilation of replies to letters regarding allowances and tolerances on wrench jaws.
 No. 47. Screw threads in electrical industry (revised).
 No. 49. National fire-hose thread (revised to national hose-thread form).
 No. 50. Questionnaire on well casing and casing threads.

The papers listed below have appeared in current scientific and technical publications:

Sieve-testing apparatus (L. V. Judson and R. E. Gould), Jour. Opt. Soc. of Am. and Review of Scientific Instruments, September, 1922.
 Simple equipment for determining the errors of screws (W. Souder), abstract in program of Opt. Soc. of Am., 7th annual meeting, October, 1922.

ELECTRICITY.

E. C. Crittenden.

FUNCTIONS.

The work of this division covers electrical units, standards, measuring instruments, and methods of measurement, including electromotive force, resistance, current, inductance, capacitance, conductivity, insulation, magnetic measurements and properties, radioactivity, radio and telephonic communication, and properties and performance of electrical equipment, such as lamps and batteries. As a result of cooperation with public service companies, public utility commissions, and municipalities on public utility problems, some of the work has been extended to cover more than strictly electrical matters.

SECTIONS.

1. Resistance measurements.
2. Inductance and capacitance.
3. Electrical measuring instruments.
4. Magnetic measurements.
5. Photometry and illuminating engineering.
6. Radio communication.
7. Electrolysis prevention.
8. Safety engineering.
9. Gas engineering.
10. Electrical service standards.
11. Telephone service standards.
12. Electrochemistry.
13. Radioactivity and X-ray measurements.

GENERAL STATISTICS.

Staff	98
Expenditures (1922-23)	\$264,000
Tests completed	7,583
Researches completed	24
Bureau publications issued	24
Other technical publications	29

WORK CHART.

I. RESISTANCE MEASUREMENTS.

SCOPE.

Establishment and maintenance of the ohm.
 Development of resistance apparatus.
 Galvanometer design.
 Study of methods of measurement.
 Testing of standards and apparatus.
 Investigation of electrical properties of conductors.
 Standardization of conductor materials.
 Applications of resistance methods.

TESTS.

Nature of test.	Number completed.		Nature of test.	Number completed.	
	1921-22	1922-23		1921-22	1922-23
Resistance standards.....	139	86	Potentiometers.....	13	7
Current shunts.....	23	17	Volt boxes.....	11	5
Wheatstone bridges.....	4	8	Conductors.....	48	50
Thermometer bridges.....		2	Miscellaneous.....	10	1
Thomson bridges.....		2			

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Fundamental measurements of resistance.....		30	
Regulation of speed of motor.....		70	
Apparatus for determination of salinity of sea water by electrical method.	Coast and Geodetic Survey.	80	
Errors caused by grounding of terminal of bridge.....		70	
Measurement of low resistance by means of a wheatstone bridge.		90	
Special purpose galvanometer.....		75	
Standardization of resistance materials.....	A. I. E. E.....	25	
Standard conductivity of aluminum.....	(¹).....	50	
Variation of metallic conductivity with electrostatic charge.		100	Outside. ²

¹ British and French national laboratories, Aluminum Co. of America.

² Physical Review, vol. 20, No. 6, p. 589, December, 1922.

2. INDUCTANCE AND CAPACITANCE.

SCOPE.

Establishment of fundamental standards of inductance and capacitance.
 Maintenance of working standards.
 Calibration of standards of other laboratories.
 Development of mathematical formulas.
 Investigation of methods of measurement.
 Measurement of electric properties of insulators: (a) Dielectric constant, (b) Dielectric loss, (c) Insulation resistance.
 Measurements on phenomena involving the determination of short-time intervals: (a) Absolute capacitance, (b) Ballistics, (c) Engineering.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Condensers.....	197	127
Inductances.....	41	47
Insulation resistance.....	17	19

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Skin effect in solenoids.....	.....	100	S422.
Mutual inductance of coaxial circles.....	.....	95	
Spectroradiometric analysis of radio signals.....	.....	100	
Methods of measuring dielectric losses.....	(1).....	50	
Ratio of absolute and international henry.....	.....	30	
Movements and stresses in turrets.....	Navy.....	90	Special report.
Supersensitive detonators.....	do.....	100	Do.
Ballistic investigations.....	do.....	90	S420.
Submarine cable insulation.....	do.....	25	
Torsional vibration of crankshafts.....	do.....	100	Special report.

¹ General Electric Co. and Westinghouse Electric & Manufacturing Co.

3. ELECTRICAL MEASURING INSTRUMENTS.

SCOPE.

Testing electrical measuring instruments and accessories (shunts and instrument transformers).

Maintenance and extension of standards and methods for measuring voltage, current, power, and energy.

Research on problems related to commercial electrical measurements: (a) Development of testing methods and apparatus, (b) Studies of dielectric strength and dielectric loss at high voltages.

Development of specifications for electrical measurements.

Miscellaneous electrical tests and investigations.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Ammeters.....	58	15
Millivoltmeters.....	8	10
Shunts.....	5	43
Voltammeters.....	3	3
Wattmeters.....	2	11
Voltmeters.....	24	16
Watt-hour meters.....	16	7
Current transformers.....	4	22
Voltage transformers.....	11	10
Rubber gloves, pairs.....	57	12
Miscellaneous insulation, samples.....	34	26
Spark plugs, etc.....	31	22
Miscellaneous.....	9	5

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Precision measurement of high voltage.....	20	Outside. ¹ Do. ² Do. ³
Constants of standard transformers.....	50	
Standardization of electrical instruments.....	A. I. E. E.....	30	
Static electricity.....	10	
Development of noninductive resistors for heavy currents.....	25	

¹ Electrical World, vol. 81, p. 1082, May 12, 1923.² Jour. A. I. E. E., vol. 42, p. 713, July, 1923.³ Technical Review, Nat. Assn. of Cleaners and Dyers, p. 173, November, 1922; p. 181, December, 1922.

4. MAGNETIC MEASUREMENTS.

SCOPE.

Development and maintenance of methods and apparatus for the determination of the magnetic properties of materials.

Testing of materials for magnetic properties.

Miscellaneous testing involving magnetic properties or magnetic effects.

Correlation of magnetic properties with other physical properties of materials with a view to the development of nondestructive tests.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Normal induction.....	39	15
Hysteresis.....	27	149
Core loss.....	23	55
Miscellaneous.....	1	4

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Magnetic comparators.....	75	S458.
Thermomagnetic analysis.....	50	
Effect of manganese on magnetic properties.....	25	
Magnetic properties and carbon content, pure alloys.....	100	S463.
Detection of burnt rifle barrels.....	Army.....	75	
Plunger electromagnets.....	20	
Effect of heat treatment on magnetic properties of permanent magnet steel.....	10	

5. PHOTOMETRY AND ILLUMINATING ENGINEERING.

SCOPE.

Maintenance of fundamental standards of candlepower.

Calibration of standard lamps and of photometric instruments.

Research on methods of measuring light.

Development of photometric instruments.

Inspection and testing of lamps purchased by the Government.
 Investigation of characteristics of lamps.
 Formulation of lamp specifications.
 Tests of lighting fixtures and accessories.
 Investigations on motor vehicle lighting, including headlights, tail lights,
 registry plates, and signals.
 Consultation service to Government departments on lighting problems.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Candlepower standards certified.....	400	257
Other candlepower tests.....	109	233
Portable photometers calibrated.....	18	11
Pentane standard lamps.....	1	1
Automobile headlight devices.....	36	47
Locomotive headlights.....	.....	3
Transmission of glasses and films.....	5	28
Samples of kerosene.....	7	10
Mantles for gasoline lamps.....	.....	9
Special lamps tested.....	5	1
Reflection factor measurements.....	3	21
Brightness standards.....	.....	1
Illumination surveys, Government buildings.....	1	2
Lamps seasoned but not standardized.....	13	30
Lamps inspected at the factory (total).....	1,646,692	¹ 1,640,485
Lamp's life tested (total).....	2,350	1,608

¹ About 20,000 additional lamps have been inspected, on which detailed reports have not yet been received, July 1, 1923.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Methods of heterochromatic photometry.....	50	Outside. ¹
Operation of integrating spheres:	
Development of special computing scales.....	100	
Corrections for color of coating.....	50	Special reports.
Measurement of reflection factors.....	Illum. Eng. Soc.	50	
Characteristics and performance curves of electric lamps.....	Continuing.	
Distribution of light in searchlight beams.....	90	
Motor-vehicle lighting problems:	Special reports.
Properties of headlights.....	10	
Illumination and legibility of license plates.....	50	
Visibility of colored signal lights.....	5	

¹ Trans. Illuminating Engineering Society, vol. 18, No. 1, p. 62, 1923.

6. RADIO COMMUNICATION.

SCOPE.

Establishment of radio standards.
 Testing of radio instruments and devices.
 Development of methods of radio measurement.
 Specifications for radio equipment.
 Wave phenomena study.
 Survey of interference.
 Electron tube research.
 Development of radio devices.
 Government radio cooperation.
 Application of radio methods.
 Radio information.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Wave meters.....	14	10
Frequency indicators.....	1	1
Decremeters.....	15	18
Variable air condensers.....	9	2
Mica condensers.....	15	.....
Inductance standards.....	2	1
Ammeters.....	7	.....
Voltameters.....	2	.....
Heterodynes.....	2	.....
Crystal detectors.....	1	.....
Samples insulating material.....	22	13
Amplifiers.....	10	.....
Amplifier transformers.....	1	.....
Electron tubes.....	.....	6

RESEARCHES.

Subject.	In cooperation with--	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Radio beacons.....	Bureau of light-houses.	100	
Radio broadcasting problems.....	25	
Aircraft radio problems.....	Army.....	100	4 Special report.
Radio direction finders.....	100	
Radio interference.....	15	Outside. ¹
Radio wave phenomena.....	10	Do. ²
Short wave radio communication.....	80	S469; outside. ³
Electron tubes.....	50	2 outside; ⁴ S449; S450; LC87.
Radio telephony.....	75	
Insulating materials.....	75	T216; S471; LC50, LC51.
Radio measurements.....	50	3 outside; ⁵ S455, S468; LC75, LC76, LC77.
Frequency standards.....	50	Outside; ⁶ LC92.
Standards of current, capacitance, etc.....	20	Special report.
Receiving sets and amplifiers.....	75	C121, C133, C137, C141; LC86, LC90, LC93.

¹ Lefax, vol. 13, p. 22, March, 1923.² Proc. Inst. Radio Eng., vol. 11, p. 75, April, 1923.³ Proc. Inst. Radio Eng., vol. 11, p. 243, June, 1923.⁴ Jour. Wash. Acad. of Sci., vol. 12, p. 412; November, 1922; Proc. Inst. Radio Eng., vol. 10, p. 373, October, 1922.⁵ Phil. Mag., vol. 44, p. 729, October, 1922; Radio News, vol. 4, p. 1618, 1923; Wireless Age, vol. 9, p. 65, August, 1922.⁶ QST, vol. 6, p. 48, May, 1923.

7. ELECTROLYSIS PREVENTION.

SCOPE.

Field research on electrolysis testing and mitigation.

Investigation of corrosive action of soils on pipes and cables and methods of reducing damage from this cause.

Development of electrical strain gauges.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Earth current meters.....		9

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Development of improved methods of electrolysis testing with the earth current meter.		Continuing.	
Investigation of electrolysis conditions and relative merits of methods of mitigation.		do	
Study of corrosive action of the soil on pipes and cables.	(1).....	10.....	
Development of electrical strain gauges.		95.....	Outside. ²
Design and testing of special strain gauges for Navy Department.		90.....	
Development of code for lightning protection.....	A. I. E. E.....	75.....	
Development of air-speed meters.....		10.....	

¹ U. S. Bureau of Soils, various cities, public utility companies, and manufacturers of materials.

² Engineering News Record, July, 1923.

8. SAFETY ENGINEERING.

SCOPE.

Preparation and revision of safety standards.

Investigations of materials and apparatus incidental to the establishment of safety standards.

Investigation of accidents and of field conditions and current practices in industry.

Cooperation with State and municipal officials in the interpretation and application of safety standards.

Cooperation with engineering, insurance, and other associations in preparation of their own safety standards.

Preparation of publications bearing on the application of safety standards.

TESTS.

No tests made in this section.

FORMULATION OF SAFETY CODES.

Subject.	In cooperation with—	Status June 20, 1923.	
		Per cent completed.	Publication issued.
Revision of Electrical Safety Code.....		50	H3.
Head and Eye Safety Code, revision.....		100	H2.
Logging and Sawmill Code (first edition).....		100	
Aeronautical Safety Code for lightning protection.....	{ S. A. E.....	77	
	{ A. I. E. E.....	30	
Elevator Safety Code, revision.....	(1).....	30	
Miscellaneous safety codes under other sponsors.....		Continuing.	
Pictorial Electrical Safety Code.....		70	
Line construction handbook.....		40	
Standards of electrical safety conference.....	(2).....	75	Outside. ³

¹ A. S. M. E. and Am. Inst. of Architects.

² Electrical Safety Conference.

³ Mechanical Engineering, vol. 45, No. 7, p. 444, 1923.

9. GAS ENGINEERING.

SCOPE.

Study of standards for gas service.
 Furnishing information to public service commissions.
 Preparation of National Gas Safety Code.
 Study of design and performance of gas appliances.
 Investigations of hazards from gas appliances.

TESTS.

No tests except in connection with research.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Revision of Circular 32, Standards for Gas Service.....		100	Outside. ¹ C32.
Relative usefulness of different gases.....	(2).....	100	Outside. ³ T222.
Efficiency and completeness of combustion of solid top and grid top ranges.....		75	
Design and performance of gas appliances (adjustable orifices, ranges, ovens, and industrial burners).		Continuing.	Special report. Outside. ⁴
Causes of carbon monoxide poisoning from gas appliances in Baltimore, Md.	(5).....	75	Special report.

¹ A. G. A. Monthly, vol. 5, No. 5, p. 317, May, 1922.

² Pub. Serv. Comm. of Maryland.

³ Gas Age Record, vol. 15, July 8, 15, and 27, 1922.

⁴ A. G. A. Monthly, July, 1922.

⁵ Dept. of Health, Baltimore, Md.

10. ELECTRICAL SERVICE STANDARDS.

SCOPE.

Study of engineering features of electric service regulations.
 Formulation and comparison of standards for electric service.
 Engineering study of street lighting practice.
 Furnishing information to public service commissions.

TESTS.

No tests made in this section.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Revision of Circular 56, Standards for electric service.....		99	Outside. ¹ C56.
Study of street lighting service and practice.....		35	
Translation of standards of American Institute of Electrical Engineers into Spanish.	A. I. E. E.....	90	
Revision of Code for Electricity Meters.....	N. E. L. A. and Assoc. Edison Illum. Cos.	5	
Graphical symbols for electrical engineering use.....	A. I. E. E.....	80	
Cooperation on street lighting committee.....	Dist. of Columbia.	25	

¹ Electric Light and Power, vol. 1, No. 1, p. 21, January, 1923; vol. 1, No. 7, p. 41, July, 1923.

II. TELEPHONE-SERVICE STANDARDS.

SCOPE.

Determination of standard measures for quantity and quality of telephone service.

Furnishing information to regulatory bodies.

Serving as consulting telephone engineers to the Federal and State governments.

Investigation of the mathematical theory of submarine cable telegraphy.

Establishment and maintenance of the standard of electromotive force.

Testing standard cells.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Standard cells.....	272	342
Telephone headsets.....	21	16
Control equipment.....	2	.....
Transformers.....	.....	4
Solenoids.....	.....	3

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Study of quantity units and basis of specifications for quality of telephone service.....	10	Continuing.
Traffic studies and coordination of Government telephone service.....	
Private branch exchange telephone service.....	10	.....
Electromechanics of the telephone receiver.....	100	.....
Theory of telephone transmission.....	75	.....
Submarine cable telegraphy with reference to terminal networks.....	40	.....
Theory of high vacuum manometer.....	100	.....

12. ELECTROCHEMISTRY.

SCOPE.

Investigation of factors affecting performance of batteries.

Testing of primary and storage batteries and materials.

Formulation of specifications and standard methods of testing batteries.

Cooperation in commercial standardization of batteries.

Study and comparative tests of rectifiers.

Research on single potential measurements.

Investigation of the silver voltameter.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Batteries, all types.....	1,402	629
Battery materials.....	4	.....
Battery containers.....	.....	4
Rectifiers.....	.....	20

RESEARCHES.

Subject.	In cooperation with—	Status June 20, 1923.	
		Per cent completed.	Publication issued.
Navy airplane batteries.....		50	
Rectifiers, all types.....		25	
Sulphuric acid.....		10	
Jelly electrolytes.....		100	
Lead antimony alloys for grids.....		80	
Tarnishing and detarnishing of silver.....		100	
Effect of paper on tarnishing of silver.....		50	
Patent electrolytes.....		10	
Storage battery separators.....		80	2 outside. ¹
Porosity of storage battery plates.....		25	
Effect of impurities in electrolytes:			
Copper, iron, platinum, and manganese.....		100	
Investigation to be continued with other impurities.		Continuing.	
Crankshaft acceleration measurements.....		100	Spec. Rept.
Dry cell performance.....		100	C 79 and outside. ²
Rate of sulphation of storage battery plates.....		100	T 225.
Specifications for dry cells.....	Fed. Spec. Bd.	100	C 139.
Specifications for storage cells.....	do.	10	

¹ Chem. and Met. Eng., vol. 27, p. 1116; Electrical World, vol. 80, p. 1386, 1922.² Chem. and Met. Eng., vol. 27, pp. 546, 603, 1923.

13. RADIOACTIVITY AND X-RAY MEASUREMENTS.

SCOPE.

Measurements and tests of radioactive materials.

Photometric measurements of selfluminous materials.

Investigation of effectiveness of X-ray protective materials.

Furnishing information to general public on radium and radium preparations.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Radium preparations.....	2, 103	2, 156
Mesothorium.....	17	7
Selfluminous.....	1, 649	1, 281
X-ray tests.....	2	3

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Measurements of gamma-ray absorption coefficients.....		90	
Survey of the physics of radiotherapy.....		10	
Circular of information on radioactivity and radioactive materials.....		100	

Detailed Report of the Year's Work.

GENERAL.

Scope of Electrical Work.

One of the most important functions of the bureau is the establishment and maintenance of the fundamental standards upon which all electrical measurements in this country are based. This includes the intercomparison of standards, extensive research in methods of measurement, and the development and improvement of subsidiary and derived standards. These standards are utilized and the results of the researches are applied in the testing of reference standards and instruments for manufacturers, testing laboratories, universities, research institutions, electric utilities, utility commissions, engineering and other interests, and various agencies of the Government. Close contact is also maintained with similar institutions in other countries so as to secure international uniformity.

The testing of electrical instruments and apparatus is of two main classes. The first is the calibration of reference standards and precision instruments for manufacturing and other institutions which themselves make or standardize instruments for commercial use or conduct research. It is through the work of such institutions that the measurements made in practice are referred back to the standards of the bureau. Secondly, a limited amount of testing of commercial electrical measuring instruments, radio and photometric apparatus, electrical, and magnetic materials is done. A large part of this testing is done for the Government departments and serves the double purpose of providing information to be used in formulating specifications and of determining the quality of materials furnished upon specifications. Some commercial testing is also done for the purpose of keeping the bureau in touch with the needs of the industries, of developing methods, and of improving apparatus and materials.

The research work has mainly to do with methods of measurement, the determination of the electric and magnetic properties of materials, and the development of those phases of engineering science in which measurement plays an important rôle. In general, this investigational work deals with fundamental properties and principles, so that the results may be applicable to a class of problems rather than being limited to the one specific problem under investigation. The work on correlation of magnetic and mechanical properties of iron and steel and in the study of insulating materials are examples.

The research work in radio communication, magnetism, radioactivity, and photometry is along lines quite similar to that in the more purely electrical measurements. Standards have been and are being developed, methods of measurement are being improved, and special problems of significance to the industries and of particular importance to the Government are being investigated. Specific examples of the projects in hand during the past year are given in the sections below.

Public Utility Investigations.

Another important activity of this division, including more of engineering and field work than most of the electrical work referred to above, is the investigation of problems arising in connection with

various public utilities, particularly electric light and power, gas, street railway, and telephone services. The work includes (1) scientific and engineering research, (2) the study of the conditions which determine the quality of public utility service of various kinds, (3) methods of testing and inspection employed by municipalities and commissions, (4) compilation of safety rules for use by the utility companies to safeguard their employees and the public, and (5) the collection and distribution of information by published papers and through correspondence.

This work is a natural outgrowth of the research and testing done by the Bureau of Standards for the public utility companies and commissions. The testing of electrical instruments and meters, of gas lamps and the standards employed in testing gas, the life testing of electric lamps, the testing of instruments used in telephone work, research on electrolysis mitigation, and similar investigations and tests connected with public utilities, have all involved standards of service. The bureau has gradually accumulated a considerable amount of information on these questions, and has been able to contribute materially to the establishment of standards of quality in several of these services. Furthermore, it has promoted with marked success the practice of settling disputed questions in this field on the basis of sound engineering and economic principles and of cooperation between interests rather than by legal controversy, and in so doing the bureau has attained a recognized position as an advisor and mediator in such questions.

The establishment and enforcement of regulations for utility services of the kinds covered by the bureau's work are recognized as proper functions of State or local governments and the bureau neither has nor seeks any legal authority to control these services. However, the mere determination of the facts regarding the quality of service rendered often involves difficult technical or engineering questions. To say what constitutes reasonably good service and whether improvements are practicable is usually not easy, as for most cities and many State commissions it is a difficult matter to judge the quality of service rendered by the utilities. Obviously, it will never be economical or desirable for each commission or city to handle these questions alone. Though they possess large and able engineering staffs or employ specialists for each separate problem the question of what is good service or whether the service in any given case is adequate, safe, and satisfactory can usually be settled only by reference to what is done under similar circumstances elsewhere in the country. In other words, standards of good practice and good service are largely determined by general experience and should be studied comparatively, using the experience of the entire country. The bureau has been doing this for several years and has demonstrated the practicability and acceptability of the method.

In many States the commissions have set standards of service for the different utilities, and most of those that have done so have been glad to make use of the bureau's assistance. It will conduce to fairness and a good understanding to have the subject studied further and to have specifications as definite and complete as possible made available for all branches of public-utility service. The work applying more particularly to public utilities is described under sections 7, 8, 9, 10, and 11 below.

Conference of Engineers of State Utility Commissions.

Since the practice of exercising control of utilities through State commissions has spread rapidly, the bureau's relations with such commissions have become more and more important. While these relations have been very cordial and mutually helpful, it has been considered desirable to arrange for some more formal method of contact with engineers of the commissions.

In connection with a meeting of the sectional committee which is revising the National Electrical Safety Code, representatives from seven State commissions visited the bureau in November, 1922, and an informal meeting was held to consider the best method of procedure for a larger conference. In accordance with decisions then reached, arrangements were completed for a general conference of engineers on March 2 and 3 at the Department of Commerce and the Bureau of Standards. More than 30 engineers, representing various State commissions, attended this conference.

The program for the conference was confined strictly to engineering problems. A number of commission engineers presented papers on matters in which they have had special experience. These included the "Grading of public utilities," "The public interest in heating value standards for gas," and the "Conservation of natural gas." There was also a general discussion on the "Grounding of electrical circuits" and on the problem of "Inductive interference."

1. RESISTANCE MEASUREMENTS.

Frank Wenner.

Fundamental Measurements of Resistance.

The work on the determination of resistances in "absolute" ohms, as distinguished from international ohms, referred to in the report of last year, has been continued. A careful study has been made of the sources of error and the precision of adjustment required for the method selected for trial. This study leads to the conclusion that it will be possible to make the errors peculiar to this method small in comparison with those which are common to all methods of making these measurements, such as those involved in the calculation of the values of an inductance from its dimensions and the determination of the speed of rotation of the driving motor. Consideration has been given to the design of inductors, such that their dimensions may be determined to a high precision and their inductance definitely calculated. The use of these in conjunction with conductors to be furnished by the inductance and capacitance section will give values for the resistance to be measured based on independently determined values for the inductances. To obtain a value for the resistance of a conductor in terms of a calculated value for an inductance and a measured frequency, it is necessary to balance the electromotive force induced in the inductance against the potential drop in the conductor. The apparatus for making this balance is nearing completion.

Regulation of Speed of Motor.

In the fundamental measurement of resistance it is necessary to have the speed of a driving motor definitely controlled. One feature

of the plan adopted for this purpose is applicable in many cases in which speed fluctuations may occur because of sudden changes in the load or in the voltage of the power supply. This feature consists in the use of a balance wheel not keyed to the shaft, which carries one element of an electrical contact, the other element being attached to a part keyed to the shaft. The contact controls an auxiliary circuit containing a source of electromotive force and also an inductance connected in series with the armature circuit. The action is such that, in effect, the time lag of operation is counteracted, so that the motor definitely synchronizes with the balance wheel. As the latter is driven by a fairly weak spring and retarded only by a small amount of air friction, there can be no sudden changes in the speed of the motor except a rapid vibration of very small amplitude.

Measurement of Low Resistance by Wheatstone Bridge (Wenner, Smith).

For the accurate measurement of low resistance it is usually considered necessary to have special bridges, because the resistance of connections can not be made negligible in comparison with the resistance to be measured. A procedure has, however, been devised by which it is possible to make such measurements with the regular Wheatstone bridge. To be definite in value, low resistances must have distinct current and potential terminals. By a proper choice of connections to these terminals the errors caused by the connecting resistances can be made relatively small, and where these errors still need to be considered they can be determined by two auxiliary measurements with the same apparatus. With a bridge in good adjustment and having a ratio arm which can be set as low as one-tenth ohm, an accuracy of one-tenth per cent or better may be obtained in the measurement of resistances as low as one-thousandth ohm.

Errors Caused by Grounding Bridge Connections (Wenner, Forman).

In some discussions of the use of bridges it is recommended that one of the detector terminals be grounded, especially if an alternating test current is to be used. This practice often materially improves the precision to which a bridge may be balanced, and consequently it has been assumed that it also increases the accuracy of the measurements. However, investigation shows that the accuracy may be decreased rather than increased. The difficulties in operation which seem to make grounding necessary may be remedied by the use of a third branch of the bridge connected in parallel with the source of the test current, or in some cases more advantageously by a third branch connected in parallel with the detector.

Salinity of Sea Water.

In cooperation with the Coast Guard, apparatus has been developed for use in determining the salinity of sea water by measurements of its electrical resistivity. The apparatus is installed on the U. S. S. *Tampa*, which is engaged in the international ice patrol work.

2. INDUCTANCE AND CAPACITANCE.

H. L. Curtis.

Inductance and Capacitance Laboratory (Moon, Sparks).

The capacitance standards of this laboratory have been maintained at a constant temperature throughout the year. Two inter-comparisons of these condensers have been made during the year, and the values have also been determined absolutely in terms of the international ohm and second. All tests have been completed promptly. Several tests have been made which required considerable research before they could be completed.

Inductance Research (Hickman, Sparks).

In a paper on the "Alternating current resistance and inductance of single layer coils" there is derived a formula by which the change in resistance and inductance with frequency can be computed. In addition, coils were constructed in which the effect could be measured. The experimental and theoretical results are shown to agree.

A paper has also been prepared on the "Mutual inductance of coaxial circles." The purpose of this paper is to present simple formulas, tables, and charts by which the computation can very easily be made.

Capacitance Research (Moon, Webster).

At the request of an industrial research laboratory the capacitance of a set of mica condensers was determined at a frequency of 5 cycles per second. This is the lowest frequency that has ever been used in this laboratory.

Measurements were also requested on a 1-microfarad paper condenser at 2,400 volts and 30, 60, 90, and 120 cycles. This voltage is nearly the maximum which can be safely put on the bureau's air condensers. The current required was also near the limiting value for the machines for this work.

Methods of Measuring Dielectric Loss (Webster).

The purpose of this investigation is to reconcile the differences which have been obtained by different methods of measuring dielectric loss. An electro-dynamometer has been constructed and thoroughly tested. Several measurements have been made by means of the bridge method, using an air condenser as a standard. A determination of the dielectric loss in several condensers by each of the two methods will be made in the near future.

Properties of Insulators for Submarine Cables (Snow, McPherson, Busse).

In conjunction with the chemical and the structural, engineering, and miscellaneous materials divisions, a systematic program has been laid out and partially completed for determining the electrical properties of such insulating materials as show promise for use in submarine cables. This work was undertaken to supply information needed by the Signal Corps. Important conclusions have already been reached, and it is planned to prosecute the work still more actively during the coming year.

Determination of the Ratio of the International Henry to the Absolute Henry (Moon).

The international henry can be determined from the international ohm and the second. The absolute henry can be determined from computations of a coil of known dimensions. The ratio of the two values is the same as the ratio of the international ohm to the absolute ohm. In order to determine this ratio, coils are being constructed whose inductance can be computed from their dimensions. Several experimental coils have been wound in order to develop a method of winding. Two large porcelain cylinders have been ground to form and are practically ready to be wound.

Movements and Stresses in Turrets and Turret Structures (Rooney).

The data obtained on the U. S. S. *California* in November, 1922, have been carefully analyzed and a report submitted to the Bureau of Construction and Repair of the Navy Department. This report shows a number of unexpected facts in regard to the stresses which occur in turret structures during gunfire.

Velocity of the Projectile Inside the Bore of a Gun (Moore).

A self-adjusting expansometer has been developed which can be used to determine the time at which a projectile passes a given plane across the gun by observing the expansion of the gun at that plane. A considerable number of experimental difficulties have been overcome. A quantitative determination will be made in the near future to determine the accuracy that can be obtained from the use of this instrument. If it is as satisfactory as the preliminary work indicates, it should entirely replace the finger method of measuring the velocity of projectiles on battleships. It will be a very great improvement over this method, since the time between shots can be very materially shortened.

Photographs of Projectiles in Flight (Sellman).

A special camera capable of taking 250 pictures per second has been used to determine the velocity of projectiles. The error in the velocity as determined by this instrument is little, if any, greater than that which results from the use of the standard Bouléngé chronograph.

Torsional Vibrations of Crankshafts (Rooney, Sellman).

In cooperation with the Bureau of Engineering, Navy Department, a test was made of the vibration of the crankshaft of a large Diesel engine. Both the amplitude and period of vibration were studied. The data have been carefully analyzed and a report submitted to the Navy Department.

The Temperature of a Short Wire Heated Electrically (Snow).

When a short wire is heated electrically, the maximum temperature which will be attained by any portion of the wire depends on the amount of heat which is conducted to the metallic terminals and on the amount of heat transferred to the surrounding medium by conduction, convection, and radiation. A mathematical and experimental study of this problem has been made in connection with a special military investigation carried on by this section. The equation giving the temperature is complicated, but it agrees closely with the experimental results.

Spectrum Analysis of Radio Signals (Snow).

At the request of the radio section an analysis was made to show how the frequency distribution in an incoming signal could be determined by measuring the current in a simple receiving circuit. A paper on this subject has been prepared and submitted to the editorial committee.

3. ELECTRICAL INSTRUMENTS.

H. B. Brooks.

Testing of Electrical Instruments.

The volume of testing of instruments for the Government was slightly less than during the preceding year, but the testing for outside parties (public utility commissions, utility companies, and individuals) increased to nearly three times the amount done last year.

Cooperation with Associations.

The section has been represented on the following committees: Instruments and measurements, American Institute of Electrical Engineers; terminal markings of electrical apparatus, Electric Power Club sectional committee; standard symbols for electrical equipment, sectional committee, American Engineering Standards Committee; and the technical committees on stranding, and on paper insulation of the sectional committee on insulated wires and cables.

As a result of the previous work on instrument standardization, the chief of the section was appointed chairman of a subcommittee of the instruments and measurements committee to study the existing foreign specifications for instruments and to prepare proposed American specifications as a basis for discussion. A paper outlining the work done abroad and presenting the proposed American specifications was presented at the June convention of the American Institute of Electrical Engineers.

Assistance was given the National Electric Light Association meter committee in the revision of 16 chapters of the Meterman's Handbook.

Federal Standard Specifications.

Considerable time has been given to the revision of a number of specifications of the Federal Specifications Board in the light of criticisms received from Government departments and outside authorities. In addition, six electrical specifications presented by the committee have been adopted and promulgated by the above board during the year.

Development of Apparatus (Brooks, Demsey, Defandorf, Wyckoff).

The construction of an absolute electrometer for directly measuring voltages up to 250 kilovolts has been resumed. Patterns for some of the larger castings are completed, and the design of the electrometer has been improved in certain details.

An apparatus for testing insulating tapes for dielectric strength was constructed and used in cooperation with the rubber section in their development of standard specifications for such material.

An auxiliary test bench has been set up for the quick preliminary checking of instruments with a very moderate degree of accuracy.

An oil-filter press has been installed to purify the oil used in the bureau's voltage transformers.

A set of inductance coils suitable for use as burdens in the secondary circuit of current transformers has been constructed. This will make it possible more readily to duplicate the burden with which the transformer under test is used in service. Several air-cooled resistance standards for use in current-transformer testing have also been constructed, and a study has been continued of the phase angle and skin effect errors which become important in such apparatus for large currents.

4. MAGNETIC MEASUREMENTS.

R. L. Sanford.

General Magnetic Measurements.

Special attention has been given to routine magnetic testing during the year, and the test procedure has been revised for the purpose of more nearly meeting the needs in this line. On the new basis two classes of test are provided. Class A tests are limited to cases where the highest attainable accuracy is necessary. For this test specimens must be sufficiently uniform and homogeneous not to introduce errors in the measurement due to the material itself as distinct from those inherent in the method of measurement. This class of test will be applied, primarily, for the calibration of standard samples for the testing of permeameters or for certain classes of research where the highest possible accuracy is required. Class B tests are to be made in the great majority of cases. The particular method to be employed in a given instance will depend upon circumstances, but, in general, the precision apparatus will not be used. The accuracy attained will depend somewhat upon conditions, but methods will be chosen which are capable of yielding results of satisfactory accuracy for the purpose for which they are to be used. In order to provide a method for the testing of small samples of materials available only in small quantities, a magnetic comparator has been developed capable of testing with satisfactory accuracy samples 6 millimeters in diameter and 10 centimeters long. This principle is also being extended for the testing of the larger specimens regularly used for routine tests.

Magnetometric Measurements.

For certain classes of research, such, for example, as the determination of the effect of high temperatures on magnetic properties, magnetometric methods are most convenient. Special apparatus has been designed and is being installed for making this type of measurement. This work is being carried on as time and resources permit, and it is hoped that eventually the apparatus will be completed so that satisfactory measurements can be made. This line of investigation offers great promise in the study of structural transformation in iron and steel during heating or cooling as revealed by corresponding changes in their magnetic properties.

Correlation of Properties.

For the development of magnetic methods for nondestructive testing of steel and steel products fundamental data on the correlation of the magnetic properties of steel with the various factors influenc-

ing its mechanical properties are important. One of these factors is chemical composition. An investigation has been under way during the year on the effect of manganese on the magnetic properties of heat-treated carbon steel. Only steel having approximately 0.9 per cent carbon has been examined so far. The effect of manganese up to 0.75 per cent for this carbon content is apparently practically negligible.

Magnet Steel.

A joint investigation with the metallurgical division has been started for the determination of the effects of composition and heat treatment upon the magnetic and other properties of various steels, with particular reference to those now used commercially or suggested for the manufacture of permanent magnets. Various special alloys have recently been developed for this purpose, but in view of the meager data generally available on the steels ordinarily used for this purpose it has seemed best to give first attention to the regular commercial types of magnet steels. As this investigation has just been started no data are yet available.

Rifle Barrel Testing.

When a rifle barrel is burnt in process of manufacture, the result is a weak barrel, which ultimately fails in service. While this type of defect is rare, the results may be serious, and the ordinary methods of inspection do not always indicate the bad condition. The magnetic properties of burnt steel are markedly different from those of steel which has received the normal treatment. For this reason a magnetic test might be expected to reveal the burnt condition. At the request of the Army Ordnance Department apparatus has been constructed to investigate the possibilities of a magnetic method for detecting burnt barrels. This apparatus is now being given a test under working conditions to see if its use as a method of inspection is practicable.

Pull of Solenoids (Fischer).

The design of solenoid-operated mechanisms is rather difficult, due to the complicated relationships involved. Apparatus has been constructed for measuring the pull of solenoids on plungers, and data are being collected as time permits on the influence of various factors on the magnitude of this pull. Such data, of which few are available, should be of value in the design of electromagnetic mechanisms.

Cooperation with Technical Committees.

The section has cooperated actively with two technical committees of the American Society for Testing Materials. The committee on magnetic properties has completely revised its specifications for standard magnetic tests during the year, and the committee on magnetic analysis has been conducting an investigation on the testing of twist drills in which the section has cooperated.

5. PHOTOMETRY AND ILLUMINATING ENGINEERING.

E. C. Crittenden.

Calibration of Standard Lamps (Willis, Aman).

Since all candlepower and illumination measurements made in the United States depend on the reference standards preserved at the

bureau, the first duty of the photometric section is the provision of calibrated standards for research, university and testing laboratories, and lamp factories. For several years the demands for such service have been so great that requests have accumulated, and the bureau has not been able to furnish standards promptly. This demand has continued during the past year, but a special effort has been made to bring the work up to date. At the close of the fiscal year there remained on hand 117 standard lamps to be calibrated, but it is hoped that all pending tests can be completed during the next few months.

Photometric Methods (Taylor, Willis).

The use of integrating spheres continues to increase, and spherical measurements, which give directly an indication of the total light output of lamps, appear likely to supersede the older methods almost entirely in practical testing. Scientific Paper No. 447 on this subject was issued during the year, and a paper on sphere photometers was presented before the Illuminating Engineering Society. Considerable work has been done on methods for correcting errors which may arise from lack of perfect whiteness of the sphere coating.

On the problem of a general method for comparing lights of different colors little progress has been made. Some tests of total transmission of colored filters have, however, given opportunity for comparison of results with those obtained by spectrophotometric methods in the colorimetry section, and the agreement obtained has been fairly satisfactory. The most important immediate bearing of this photometric problem is on the relative values to be assigned to incandescent lamps in which the filaments operate at different temperatures and correspondingly different colors. As was indicated in last year's report, the bureau is maintaining independently sets of reference standards representing the three most important types of lamps (carbon filament, vacuum tungsten, and gas-filled tungsten), pending international agreement on a general method of comparing these types.

Inspection and Life Tests of Electric Lamps Purchased by the Government (Skogland, Anderson, Collins).

As during the fiscal year 1922, the quantity of lamps ordered by Government departments during the fiscal year 1923 was considerably smaller than for several years preceding. The aggregate number was about 1,355,000 lamps, valued at \$353,000. The average cost per lamp was about 26 cents, as compared with 30.4 cents in 1922. This difference in unit cost is largely accounted for by the two reductions in the price of tungsten lamps which were made during the year.

Of the total number of lamps purchased 86 per cent were large tungsten lamps as distinguished from miniature and carbon lamps. The corresponding percentage in 1922 was 79. The increase in tungsten lamps was largely in the vacuum type and was due to the adoption of mill-type tungsten lamps instead of carbon lamps, formerly used extensively by the Navy Department. The quantity of carbon lamps was thus reduced to about 3.5 per cent of the total. Of the large tungsten lamps 15.4 per cent in number and 33.3 per cent in cost were of the gas-filled type.

Since several large orders placed late in the fiscal year 1922 were inspected during the current year, more lamps were inspected than were actually ordered during the year, the total being about 1,640,-500. As samples representing these inspected lamps there were subjected to life test at the bureau during the year, 1,318 vacuum tungsten, 216 gas-filled tungsten, and 74 carbon lamps, a total of 1,608.

The bureau also made tests on about 350 samples representing a number of brands of lamps submitted to the States of New York and Illinois in competition for State contracts. Late in the year an inspection of one factory was made at the request of the State of Pennsylvania in connection with its contract for the coming year. These special inspections and tests for the various States have given the bureau considerable information regarding brands of lamps which are not included in the testing work regularly done for the Federal Government.

In connection with the preparation of reports on the life tests, considerable time has been given to the study of lamp characteristics and mortality curves showing the scattering of lamps from the average in regard to length of service. A large amount of detailed data on performance of lamps has also been compiled for the information of the various factories which furnished lamps to the Government. In one case a considerable study was made in cooperation with the metallurgical division on crystallization of filaments as affecting the life of the lamps.

Specifications for Incandescent Electric Lamps.

The tenth edition of Circular No. 13, United States Government Specifications for Large Tungsten Filament Incandescent Electric Lamps, was issued during the year, and this revised specification was adopted by the Federal Specifications Board for the use of the various departments of the Government.

Reflection Factor Measurements (Willis).

Some years ago several types of instruments for measuring the reflection factors of surfaces were developed at the bureau. These instruments mark a decided improvement in accuracy as compared with earlier forms. During the past year, however, questions have arisen regarding the relative values for reflection factors obtained in different laboratories. In order to determine the cause of these discrepancies comparative measurements made in four different laboratories have been arranged. Up to the present time the results obtained have indicated that there are important differences between these laboratories, but an explanation has not yet been found.

Motor Vehicle Lighting (Smith, Malamphy).

Continuing the activities in behalf of uniformity of State requirements, which were mentioned in last year's report, the bureau has carried on several projects during the year. These have included tests of headlight devices, a study of the illumination required to render license plates legible under various conditions, and several investigations intended to show the effect of variation in reflectors and lamps on test results.

At the request of the Washington Safety Council and the special traffic committee appointed by the Commissioners of the District of Columbia the bureau drew up a set of headlight regulations for the

District. These regulations have not yet been adopted, but since they are in conformity with those of neighboring States it is believed that eventually they will be accepted. In connection with this assistance given to the District two lectures were given to chauffeurs as a part of the course arranged by the Safety Council. Simple instructions for the adjustment of headlight devices were prepared and a special demonstration was given for garage men in the District. In order to show the need of more attention to adjustment of devices, a series of tests on cars in service was made. These tests included over 400 cars and showed definitely that a very large percentage of them, even when equipped with approved devices, were not in satisfactory adjustment. In this work the automotive section of the bureau cooperated, and a paper describing the general results of the tests was prepared.

Miscellaneous Illumination Problems (Willis).

The bureau was called on to give advice in regard to illumination in several Government buildings, including the Patent Office and some rooms of the Post Office equipped for special tests. Advice was also given in regard to instruments and general procedure in a survey of post-office workrooms carried out by the Public Health Service.

An extensive test of gasoline mantle lamps was made at the request of the Department of Justice to determine the relative performance of mantles of different brands.

Assistance in the calibration of instruments and special filters was rendered to several offices of the Department of Agriculture concerned with measurements of light as affecting the growth of plants.

As a continuation of measurements made at the bureau immediately following the war some work has been done on the properties of searchlight beams, with particular reference to the distribution of light in them. The section has also been charged with responsibility for investigations on the use of colored signals for control of traffic to be made in connection with code work on this subject managed by the safety engineering section.

6. RADIO COMMUNICATION.

J. H. Dellinger.

Radio Interference.

With the increasing use of radio communication it becomes more important to reduce the interference between radio waves. This means that all transmitting stations must operate exclusively on the frequencies assigned them, must use as small power as required to reach the necessary distance, and must use waves which are as sharp as possible. One of the immediate objectives of radio research generally, and of the bureau's radio work particularly, is the reduction of radio interference in each of these respects. The requirement of a sharp wave means that the radio wave must occupy as narrow a band as possible in the wave-frequency spectrum. The breadth of the wave is therefore a measure of its interference-producing quality, and for this reason a research has been started on the measurement of the breadth of waves. The particularly difficult problem of correction for the effect of the receiving circuits used in any such measurements is being studied. Experiments have been commenced also on the

effects of modulation and frequency variation on the breadth of waves.

Electrical (nonradio) interference with radio reception is becoming increasingly important. While the bureau has done little experimental work on the subject, it has made a preliminary study of it and has had much correspondence on the matter. The National Electric Light Association, Institute of Radio Engineers, American Radio Relay League, and many other radio and electrical interests have urged that the bureau undertake a comprehensive study of the problem, but the necessary means have not yet been provided. Radio reception is frequently interfered with and in some cities almost entirely prevented by electrical disturbances from such sources as series arc circuits, battery chargers, power lines containing sparking commutators, leaky insulators, telephone bell ringing magnetos, and electrical precipitation processes.

Statistical Study of Distance Range (Jansky, Engel).

Along with the study of methods of measurement of interference, work has been conducted to determine the actual extent and effect of interference in radio reception as experienced by broadcast listeners. A statistical study of distance range of radio transmission from broadcasting stations has been made, the observations being taken by about 100 volunteer observers. The bureau had the cooperation of the American Radio Relay League, the Westinghouse broadcasting station at Pittsburgh, and the University of Minnesota in selecting observers and editing the observation forms, about 7,200 of which were received. These are being analyzed by the sorting and counting machines of the Bureau of the Census. The results show the effect upon distance range of the distance, wave frequency, type of receiving apparatus, and various sources of interference. The analysis of results to date shows that the principal obstacle to reception is interference from broadcast stations other than the one which the listener desires to hear. The next greatest obstacle is fading of signals (except in the summer when atmospheric disturbances are worse), and the smallest of the observed obstacles to reception is interference from power lines. The results showed that there is a region of minimum reception about 100 miles from a transmitting station, such that louder signals are received both nearer to and farther from the transmitting station than in this region. The distance of this region from the transmitting station is roughly proportional to the wave length.

Radio Fog Signalling (Dunmore).

Cooperation with the Bureau of Lighthouses in the improvement of the radio fog-signalling service was continued. An automatic transmitting set of Bureau of Standards type was adjusted in a new beacon station near Baltimore. Preliminary specifications were prepared for an automatic transmitting set of electron-tube type. Such sets will give rise to much less interference with other radio communication, will modernize the beacon system, and will have greater distance range. Some consideration was given to the improvement of design of direction finders for use on shipboard.

Radio Recorders.

A radio time-signal relay was designed and constructed for the recording of Arlington time signals by the section of the bureau dealing with time standardization. This relay is essentially a receiving set adjustable to a single frequency and is very rugged and positive in action.

Aircraft Radio Problems (Dunmore, Engel).

Work was carried out for the Air Service on the development of an altimeter utilizing variations of capacitance detected by radio methods. Reports on this subject were furnished to the Air Service. Special work on the application to aircraft of radio communication on 3,000 kilocycles was also done (see "Short wave radio communication" below).

Radio Wave Phenomena (Whittemore).

A paper describing the bureau's work on the fading or fluctuations of short wave radio signals was sent to press. This paper is to be issued as a scientific paper of the bureau and an abbreviated version is to appear in QST. A paper has also been prepared on the methods of statistical analysis used in the foregoing work and in the study of distance range.

The bureau is represented on the committee on earth currents and polar lights of the American Geophysical Union, which is making a study of the effect of aurora on radio transmission. Observation forms for radio and aurora conditions were prepared for the McMillan Polar Expedition in cooperation with the American Radio Relay League and Carnegie Institution. The purpose of these forms, to be filled out by observers on the expedition and on land in the northern parts of North America, is to reveal relations between radio and auroral phenomena.

Assistance was given in the preparation of programs and general organization of work on radio phenomena in connection with the International Union of Scientific Radio Telegraphy (see paragraph on this subject below).

Short Wave Radio Communication (Dunmore, Engel).

A research has been under way for the Air Service of the Army on the practicability of radio communication at higher frequencies than those used in the past. The use of such frequencies, largely neglected heretofore, has been found to have a number of important advantages. Interference is less because a much narrower percentage band of frequencies is utilized by radio telephony or any given type of modulation than at lower wave frequencies.

Apparatus was developed for both transmission and reception on a frequency of 3,000 kilocycles per second (100 meters). Both telegraphy and telephony on this frequency were found to be thoroughly practicable. In two-way tests between Washington and Pittsburgh it was found that the fading was materially less than in communication at lower frequencies.

When the experiments were carried to a frequency 10 times the foregoing, namely, 30,000 kilocycles per second (10 meters), it was possible to concentrate the waves in a desired direction by means of a parabolic cylindrical reflector of parallel wires. Both tele-

graphy and telephony were accomplished under these conditions. Special 100-watt generating apparatus was developed, and the signals were received by a small loop antenna.

Electron Tubes (Jolliffe).

A study was made of the effect of regeneration in receiving sets. It was found that the amplification due to regeneration decreases with increase of signal strength and that the effect of regeneration is not strictly equivalent to a negative resistance for different values of current in the circuit. A study was made of various means of preventing reradiation from regenerative receiving sets. This is an important phase of the interference problem, since the disturbance radiated from such sets gives rise to annoying noises in the receiving sets of near-by users. A brief experimental study was made of super-regeneration.

Life tests were undertaken on the newer types of receiving tubes. This work is in progress in cooperation with the tube manufacturers and the Navy and the Army. It has involved a selection of properties for periodic measurements and the establishment of a time schedule for the routine of the life tests.

A study of the power rating of power tubes is under way. Two radio telephone sets for general laboratory use and for the transmission of standard frequency signals have been constructed.

Insulating Materials (Preston, Strock).

Measurements of radio-frequency properties were made on a number of samples of phenolic insulating material, hard rubber, celluloid, and miscellaneous materials.

Work was also carried out on the standardization of methods of testing the properties of electrical insulating materials in cooperation with the American Society for Testing Materials, the bureau being represented on committee D-9, insulating materials. The bureau's methods of measuring radio-frequency properties were adopted by this committee as tentative standards.

Radio Measurements.

In cooperation with the Radio Inspection Service a number of improvements were made in the wave meters used by the radio inspectors. Specifications were drawn up for the design and construction of two coils to increase the frequency range of the wave meters. Improvements were made in the resonance indicators. A special scale was designed for use with the instrument which increases the precision of reading frequency or wave length by a factor of six. This work has been essential in view of the increasing use of continuous wave radio-transmitting apparatus and the closer spacing of wave frequencies assigned to radio stations.

A differential measurement device for rapid radio-frequency measurements was designed and constructed. The cathode-ray oscillograph tubes used in connection with fundamental frequency standardization were improved by evacuation by special apparatus, and measurements were made on the radio-frequency impedance of a number of telephone receivers.

Design of Radio Standards (Preston).

A number of improvements were made in the design of the variable air condensers used as radio-frequency standards. A series of special

inductance coils was designed which gives a comprehensive set of standards for inductance and frequency measurement in a radio laboratory.

The Radio Inspection Service was assisted in the design of a very compact wave meter for the broadcast range of frequencies. Two designs were prepared for a frequency indicator; that is, a non-adjustable wave meter, which indicates at one frequency only. This device is for use in a broadcast transmitting station to set the frequency accurately on the assigned frequency. The use of a device of this type was recommended by the Second National Radio Conference.

Improvements in Frequency Standard.

The increase in the use of radio communication and particularly radio telephony has required that radio transmitting stations be set more accurately than in the past on the exact assigned wave frequency. In order to minimize interference it appeared desirable to assure the accuracy of such setting to 0.1 per cent, and this required that the bureau increase the accuracy of its frequency standardization of wave meters. This necessary extension of accuracy has been made and its validity assured through the use of four independent methods of establishing a standard of frequency. One of these is the calculation of frequency from inductance and capacitance embodied in carefully constructed standards, such that the values are the same at radio frequencies as at low frequencies. The second method is a step-up to radio frequencies from the frequency of a carefully standardized tuning fork by means of frequency ratios determined by the cathode-ray oscillograph. This method is capable of extreme accuracy. The third method is a step-up from the frequency of a tuning fork by the use of harmonics of an electron-tube generator, while the fourth method is the step-down to radio frequencies from ultra radio frequencies, such that the corresponding wave length can be measured by means of short standing waves on parallel wires.

Besides the establishment of a more accurate frequency basis the problem involves the production and maintenance of standards which will preserve a very constant frequency basis. This has involved studies of accurate wave meter design. Some measurements were made on piezo-electric resonators, which are extremely compact, and will be given further study as accurate frequency standards. While the work which has been done in improving the accuracy of frequency measurements has had gratifying success, it now appears necessary to go still further, and the problem will be continued with a view to securing an accuracy of at least 0.01 per cent in the bureau's frequency standard.

Standard Frequency Transmission (Walls, Hall).

Frequency is a quantity of which the standard can be made available without the necessity of transporting physical instruments. Advantage has been taken of this property to extend greatly the availability of the bureau's frequency standard by the transmission of radio signals of standard frequency. A special radio telegraph and telephone transmitting set was constructed for this purpose. Following two preliminary transmissions, which incidentally re-

sulted in a direct comparison of the actual state of calibration of wave meters in use, signals of standard frequency have been transmitted about once in two weeks. The schedules and other details are announced in the press and in the Radio Service Bulletin. The frequency range from 75 to 2,000 kilocycles (4,000 to 150 meters) has been covered.

The frequency basis of the bureau is made available also by measuring from time to time the frequency of the wave actually transmitted by various stations to check their use of the frequencies assigned them, to check their degree of constancy, and to determine whether their transmission is of a sufficiently constant frequency to make them available as frequency standards. It is proposed to announce the frequencies of stations which have shown themselves to be in the latter class, such stations then becoming available as points of a standard frequency scale.

Receiving Sets and Amplifiers (Whittemore, Preston, Strock).

Measurements were completed on the characteristics and performance of 34 commercial receiving sets of a wide variety of types and frequency range, and further study and improvements were made of the methods of measuring sensitivity and selectivity.

A series of five circulars on the construction and operation of very simple radio receiving sets was prepared, and in connection with this work models of these sets were constructed. These sets have been received with favor by many of the younger amateurs and are now in wide use.

Measurements were made of the voltage amplification and input impedance of 17 commercial audio-frequency amplifiers.

Radio Testing (Hall).

The apparatus for radio testing was improved. A convenient set-up for capacitance measurement at radio frequencies was prepared, and an additional working standard wave meter was provided with devices for precise adjustment to resonance. A considerable amount of the testing was for the Radio Inspection Service. Certain of the parts used in the wave meters employed by the radio inspectors were put in stock to avoid delays in testing.

Much more testing was requested by various institutions and individuals than the bureau could handle. In order to inform persons whose tests the bureau was compelled to refuse for various reasons, the qualifications of a number of private testing laboratories were investigated, and a list of such laboratories is now given applicants for tests which the bureau itself can not make. The testing of wave meters at other places than in the bureau's laboratory is now facilitated through the standard-frequency signals which are periodically transmitted; such standardization is better than a wave-meter test made at the bureau, since the wave meter does not have to be transported.

Standardization of Radio Equipment (Whittemore).

A national movement for the standardization of radio apparatus and service was launched by the bureau. At the request of the Institute of Radio Engineers, the National Radio Chamber of Commerce, Associated Manufacturers of Electrical Supplies, the National Retail Dry Goods Association, American Radio Relay League, Radio

Corporation of America, and the American Engineering Standards Committee the bureau called a general conference of all radio interests on January 12. The result of this conference was the formation of a sectional committee of the American Engineering Standards Committee for radio standardization. Since the conference the bureau has participated in the preliminary work of organizing the sectional committee.

The bureau has been represented on the standardization committee of the Institute of Radio Engineers, which recently completed its work, in progress for some years on the standardization of radio nomenclature and graphical symbols. The results of this study have been published in the 1922 report of the committee on standardization of the Institute of Radio Engineers.

Extensive correspondence was carried on with manufacturers of radio apparatus in connection with the revision of Letter Circular No. 66, List of Manufacturers and Sole United States Distributors of Radio Receiving Equipment. This work progressed to the stage where it could be more properly handled by the electrical equipment division of the Bureau of Foreign and Domestic Commerce. It is now issued as a pamphlet by that bureau under the title, "List of Manufacturers and Sole Distributors of Radio Apparatus and Parts."

Radio Information (Ould, Zandonini).

The volume of requests for radio information of all kinds was far beyond the ability of the bureau to handle adequately, but was not as great as in the previous year. The amount of time required to handle this correspondence has been reduced through systematization of types of letters used in reply and of reference files and other sources of information.

An information service provided by the laboratory which has won much commendation from technical radio workers is the reference lists which are published each month in the Radio Service Bulletin. The preparation of these monthly lists was begun two years ago, but it was not until August, 1922, that they appeared in printed form. They furnish a classified list of references to the principal radio articles of technical interest appearing in the current periodical literature.

Second National Radio Conference (Dellinger, Whittemore).

A conference was called by Secretary Hoover on March 20 to 24 to advise him in the administration of the radio laws. The bureau participated in this conference, which represented United States radio interests generally. The result of the conference was the assignment of new wave frequencies throughout the whole radio range, so chosen as to reduce interference which has become excessive. The conference made a number of other recommendations which are proving of assistance to the department in its difficult task of administering the radio laws and international convention which have become obsolete from the technical standpoint.

Interdepartment Radio Advisory Committee (Stratton, Dellinger, Whittemore).

The committee, which was organized toward the end of the previous fiscal year, has proved successful in coordinating the radio

work of the Government. The scope of the committee's work was extended during the year from radio broadcasting to all radio matters. The bureau's representatives participated in the work of various subcommittees, particularly that of the subcommittee on technical problems. Through the work of this subcommittee a complete list giving all essential details of the equipment and operation of all Government radio stations has been prepared for the first time. The committee has carried on important studies of radio interference and has begun a general program of standardization of radio equipment. The report of the work of the committee was issued by the Department of Commerce May 28.

International Union of Scientific Radio Telegraphy (Dellinger).

The bureau assisted in the work of this organization, which is promoting international cooperation on some of the larger problems in radio communication. The problems include radio wave transmission phenomena, atmospheric disturbances, methods of measurement and standards, and measurement of radiation causing interference. University and other research workers were consulted on various phases of the technical problems under study.

General Radio Work.

The bureau cooperated with a number of organizations in radio matters besides those mentioned in the foregoing. Among such organizations may be mentioned the American Radio Relay League, to which information was furnished on the various problems. The bureau participated in the work of a radio committee, consisting of representatives of the several bureaus of the Department of Commerce having to do with radio matters. This committee was useful in coordinating the department's radio work touching broadcasting, the marine direction finder, radio regulations, and preparations for the future international radio conference.

The bureau has taken the lead in undertaking to introduce the concept and unit of frequency instead of wave length in radio work. This practice was recommended by the Second National Radio Conference. An accurate and convenient table for converting kilocycles and meters was prepared, and this, together with a statement, "The use of kilocycles in radio," was issued to the press May 7.

Exhibits showing the radio work were furnished to a number of expositions and the model showing the radio fog signaling system was loaned to the Second Annual Marine Exposition in New York and to an exposition in Atlanta, Ga.

7. ELECTROLYSIS PREVENTION.

Burton McCollum.

Electrolysis Work.

Electrolysis testing and mitigation heretofore have been handicapped by very inadequate methods of determining electrolysis conditions because methods of test formerly available did not give a direct measurement of the factor causing corrosion. About two years ago there was developed at the bureau an earth current meter, which is an instrument for accurately measuring the currents directly responsible for electrolytic corrosion. This apparatus measures the

leakage current in the earth near the pipe or cable and permits an accurate determination of electrolysis conditions at the point of test. During the past year the instrument has been used extensively in field work in a number of cities, partly for the purpose of developing the procedure in applying the apparatus to electrolysis testing and partly to acquaint engineers with the possibilities of the new method. The new instrument also makes it possible to study the relative merits of different methods of electrolysis mitigation in a much more definite and accurate way than was possible under the older methods of test, and considerable application of the instrument has been made by the bureau in this field.

As a part of the study of errors involved in electrolysis testing a large amount of laboratory work has been done on the galvanic and polarization potentials which are set up between metals under conditions which might occur on public-utility networks. It has been demonstrated that the ordinary potential difference measurements between a pipe and a near-by point in the earth as made heretofore may include a galvanic voltage of a tenth of a volt or more and thus give rise to very misleading conclusions. This not only shows that such tests, largely relied upon in electrolysis testing, are inaccurate, but shows also that such galvanic voltages may often be an important factor in the deterioration of pipe and cable networks.

Soil Corrosion (Logan).

The soil-corrosion investigation was started in 1922, chiefly for the purpose of determining the extent of the corrosive action of different kinds of soil on various kinds of metals used for pipe purposes and of determining the importance of this corrosion in diagnosing cases of damage alleged to be caused by stray currents. This work has been expanded, at the urgent request of pipe manufacturers and of many public-utility corporations, to include a study of the effectiveness of bituminous and metallic coatings as a protection against soil action. Eight bituminous coatings and four kinds of metallic coatings are being tested in a large number of localities carefully selected throughout the country. This work is being done with the active cooperation of the public-utility companies in many parts of the country, pipe manufacturers, and the Bureau of Soils of the Department of Agriculture.

Electric Telemeter (Peters).

In last year's report mention was made of the fact that this section had under development a series of electric telemetric (remote reading or recording) devices of the carbon-resistor type, and that these devices were finding application in the measurement of strains, stresses, and forces, particularly those of rapidly varying character. During the year considerable progress has been made in this work, and the following pieces of field and laboratory apparatus have been constructed:

1. A six-element photographic field outfit of the carbon-resistor type for measuring strains in steel structures due to live loads. With this apparatus simultaneous photographic records may be made of vibratory strains at six widely separated points, having frequencies of as high as 100 cycles per second.

2. A calibrating device with a micrometer microscope suitable for calibrating carbon-resistor gauges for field use and also for studying the performance of resistor elements in detail.

3. An indicating panel for laboratory use in studying forms of gauges and checking their constancy for laboratory use.

4. Three single-element indicating strain gauges for laboratory use.

5. One four-element pull indicator for measuring the pull on the pressure arms of a set of dynamometers for testing brake-band material.

Research on high-resistance carbons has also been carried on, and it is now possible to make carbon resistors ranging in resistance from 10 to 100 ohms each and having a working range of 50 per cent of the initial value; that is, a 100-ohm stack would have a working range of from 100 to 150 ohms. These values permit the use of much longer leads than have been used heretofore and make the design of indicating instruments a simpler matter than with low-resistance stacks.

Several new forms of mountings for carbon resistors have been made for the purpose of minimizing the exaggeration of effects due to vibration and to buckling or bending of structural members. A large amount of work has also been done in cooperation with the Bureau of Aeronautics of the Navy Department and the Air Service of the Army in the design, assembly, and calibration of apparatus for their special purposes.

8. SAFETY ENGINEERING.

M. G. Lloyd.

National Electrical Safety Code.

The bureau has been engaged for 10 years in a study of the life hazard in electrical practice and in the preparation and application of the National Electrical Safety Code. In this work it has had the cooperation and assistance of a large number of engineers connected with electrical operating and manufacturing companies, State commissions, municipalities, and insurance underwriters. The electrical workers and the various national associations in the electrical industry have also cooperated effectively in this work. The importance of having a national code, uniform in all the States, is generally realized, as is also the advantage of having such a code prepared and presented by a national agency that can study the subject thoroughly and consult all the interests affected. The Electrical Safety Code consists of four principal parts, as follows:

1. Rules for the installation and maintenance of machinery, switchboards, and wiring in central stations and substations.

2. Rules for the construction and maintenance of overhead and underground lines for the transmission and distribution of electrical energy and intelligence.

3. Rules for the installation and maintenance of electrical apparatus and wiring in factories, residences, and wherever electricity is utilized for light, heat, or power.

4. Rules to be observed by operators in working on or near electrical machines or lines.

A supplementary section includes rules for the grounding of circuits and equipment.

The bureau's thorough study of the diverse conditions under which electricity is generated, distributed, and utilized and of the effect of the rules on operating and construction costs has secured a code which involves no unreasonable expense, but, in general, assures an adequate measure of safety and a useful standardization of practice. The varying conditions in different geographical sections and in thickly and thinly populated districts have been given careful attention.

The third edition of the code was published under date of October 31, 1920, as Handbook No. 3. The discussion was separated from the rules and issued as a separate volume known as Handbook No. 4. Both the rules and the discussion were extensively revised and amplified, and this edition of the rules is in suitable form for adoption by State commissions, municipalities, and other agencies having appropriate jurisdiction.

Such mandatory application of the rules is already being made, the States of Iowa, Nevada, North Dakota, Oklahoma, Oregon, Tennessee, and Wisconsin having adopted rules based on the third edition. Other administrative bodies had previously adopted rules comprising this code in whole or in part, and it is generally recognized as the most complete and satisfactory standard in its field. This code has been approved by the American Engineering Standards Committee as an American standard. Part 2, dealing with overhead line construction, is being revised, with the assistance of a sectional committee under American Engineering Standards Committee procedure, preparatory to a fourth edition.

A pictorial edition of the rules showing their application by illustrations is in course of preparation. It is also expected to publish a volume of engineering data referring to matters connected with the rules or with overhead line construction. These data will include more extensive tables for the sags of conductors and will include tables regarding the supporting structures, such as wood and concrete poles and steel towers.

Electrical Safety Conference.

The Electrical Safety Conference, organized to promote the orderly, consistent, and proper development of practice in electrical manufacturing and installation with regard to accident hazards, includes representatives of the Associated Manufacturers of Electrical Supplies, the Electric Power Club, the National Bureau of Casualty and Surety Underwriters, Underwriters Laboratories, National Electric Light Association, Association of Electragists-International, and the Bureau of Standards. Detailed standards for construction and installation of apparatus are being worked out by the conference in harmony with the Electrical Safety Code. The conference has already adopted standards for industrial control equipment, rotary machinery, switchboards, and oil switches and circuit breakers. Others are in course of preparation, those dealing with panel boards and inclosed switches being nearly completed.

Safety Code for Lightning Protection (Peters).

As joint sponsor with the American Institute of Electrical Engineers, the Bureau of Standards has organized a sectional com-

mittee of the American Engineering Standards Committee to prepare a code for the protection of buildings and other property against lightning. This work will consist of three parts: (1) The protection of persons, buildings, livestock, ships, smokestacks, trees, balloons, airships, and hangars; (2) the protection of structures containing inflammable liquids and gases; and (3) the protection of electrical lines and apparatus. The first part of the rules, including specifications for lightning rods and rules for safeguarding human life, has been the subject of a number of committee meetings and much correspondence with interested persons throughout the country and is now approaching its final form.

Industrial Safety Standards.

As a result of the work on the National Electrical Safety Code and the numerous points of contact thus established with State authorities and others interested in safety work, the bureau was called upon to enlarge the scope of this work and to consider safety requirements in other than the electrical industry. Two large and representative conferences held at the bureau in 1919 decided that all of this work should be placed under the auspices of the American Engineering Standards Committee, which was reorganized and enlarged as a result of these conferences. Provision was also made for the formation of a joint safety code committee to prepare a list of codes already in existence or urgently needed and to recommend sponsors for preparing and revising these codes. This committee has since been succeeded by the Safety Code Correlating Committee, upon which the bureau is represented. Recommendations have been made to the American Engineering Standards Committee for a large number of safety codes and most of the recommendations have been approved by that body.

The Bureau of Standards has, upon invitation from the American Engineering Standards Committee, accepted sponsorship for the following codes:

Electrical safety code.

Gas safety code (joint sponsorship with the American Gas Association).

Code for the protection of the heads and eyes of industrial workers.

Combined electrical fire and safety code.

Code for protection against lightning (joint sponsorship with the American Institute of Electrical Engineers).

Safety code for logging and sawmill operations.

Safety code for aeronautics (joint sponsorship with the Society of Automotive Engineers).

Code for the colors of traffic signals (joint sponsorship with the National Safety Council and American Association of State Highway Officials).

Safety code for elevators (joint sponsorship with American Society of Mechanical Engineers and the American Institute of Architects).

A large number of safety codes are being developed by sectional committees organized by other Federal bureaus and engineering societies as sponsors. The bureau is represented upon many of these committees and is doing active work in the development of the codes under their jurisdiction.

Code for Head and Eye Protection.

The National Safety Code for the Protection of the Heads and Eyes of Industrial Workers was first issued in 1921. During the

current year a second edition was published. This code states the type of protection needed in various occupations and processes and includes specifications for goggles, helmets, and other devices which provide such protection. It has been generally recognized as the most authoritative work upon this subject and has been approved by the American Engineering Standards Committee.

Logging and Sawmill Code (Dickinson).

After several years of work in field inspections and a study of the processes followed in this industry the preliminary rough draft of this safety code has been revised and improved until it now represents a standard for practice which provides the safety requirements so much needed in this hazardous industry. This code covers the felling of standing timber; the transportation of logs to the sawmill by the various methods of skidding, river driving, and railroading, including the use of donkey engines and boilers; the storage and use of explosives; and the operations of transforming logs into dimension lumber at the sawmill, including the operation of dry kilns. The code is now complete and ready for publication, having been approved by the sectional committee which has cooperated with the bureau in its formulation. This committee included representatives of the chief lumber interests, State labor officials, manufacturers of logging and sawmill equipment, timber workers, and insurance companies, as well as other experts on the subject.

Aeronautical Safety Code (Halsted).

This code will include requirements for the construction and operation of airplanes, airships, and their power plants; requirements for landing fields for balloons and for parachutes; and will specify the qualifications for aviators and the traffic rules to be observed in the navigation of the air. Parts dealing with balloons, airships, and landing fields have been completed, and work upon the remaining parts of the subject are nearing completion. This work has been carried out in cooperation with the Society of Automotive Engineers and a committee representative of the various interests concerned in this industry.

Elevator Safety Code (Dickinson).

An Elevator Safety Code has already been published by the American Society of Mechanical Engineers, members of the bureau's staff having taken an active part in its preparation. As a joint sponsor the bureau is now taking part in the revision of this code. The next edition will contain not only rules for the construction and installation of new elevators and escalators, but also a separate set of rules for existing installations.

Publications and Addresses.

An important part of the work of this section is the furtherance of education of engineers, workmen, and others in safety subjects. For this purpose a considerable number of technical and popular papers and addresses have been prepared and presented during the year.

9. GAS ENGINEERING.

W. M. Berry.

Standards for Gas Service.

The bureau has continued to receive many inquiries from municipalities and State public utility commissions regarding standards for gas service. One of the most important cases was that of the State of New York, where a specific heating value was established by legislative action. In connection with this action the bureau was called on for advice by both the State Public Service Commission and the American Gas Association. The suggested rules given in Circular No. 32, Standards for Gas Service, have been widely adopted, and there has been a large demand for the fourth edition of this circular, which was issued in 1920. During the year a large amount of work has been done in completing the revision of that part of the circular which summarizes State and city regulations now in force. While conditions with regard to gas-making supplies and materials have changed considerably, the general principles governing the establishment of service regulations have not been affected thereby. Consequently, the discussion of technical requirements and the recommendations regarding rules and ordinances given in the fourth edition of Circular No. 32 have not required modification. In view of the shortage of printing funds it has, therefore, not appeared advisable to print a new edition of the whole circular. The more important parts of the revised material on current regulations have been printed in the American Gas Association Monthly, and the complete data are available for reference.

During the year reports have been published dealing with the investigation carried on last year in cooperation with the Maryland Public Service Commission to determine the most economic heating value standard for the city of Baltimore. The laboratory investigations are reported in Technologic Paper No. 222, on Relative Usefulness of Gases of Different Heating Value and Adjustments of Burners for Changes in Heating Value and Specific Gravity. This material was also published in the general report of the investigation issued by the Public Service Commission, and the more essential parts were given in a series of articles in the Gas Age Record beginning in July, 1922.

Utilization of Gas (Brumbaugh, Eiseman, Shawn).

As during the preceding year, a large part of the section's work has been on various appliances for using gas. The previous work on design of burners has aroused wide interest among manufacturers, and the bureau has been called upon to test and criticize a large number of designs for various purposes. Special attention has also been given to the development of improved adjustable orifices. This work in particular has been done in close cooperation with representatives of the American Gas Association and several important manufacturers. The apparatus used for burner testing was demonstrated at the annual convention of the American Gas Association in October, 1922, and attracted a great deal of attention. Its ready applicability to tests of burners under various conditions has made possible extensive investigations of the performance of

appliances which have given much more definite results than would otherwise have been attained.

The bureau has been represented on several committees of the American Gas Association, including the industrial fuel sales committee, the chemical committee, and the managing committee of the technical section. This close contact with the technical committees of the association has been of very great value in directing the bureau's work along practical lines.

Special attention has been given during the year to tests of a large number of devices which are claimed to increase the efficiency of use of gas but which involve more or less hazard because of resulting incompleteness of combustion. These have included various types of so-called "gas savers," devices which are to be placed on top of regular burners, and also solid tops to be placed on ranges of the open grid type. In general, it has been found that these devices are of doubtful value in increasing the efficiency of use and that they certainly increase the dangers of poisoning from carbon monoxide. Considerable attention has also been given to completeness of combustion obtained in heaters of the radiant type. These heaters are very popular, but if not well designed they also may give rise to hazards because of incomplete combustion of the gas.

Investigation of Gas Poisoning in Baltimore (Brumbaugh).

A large number of deaths from gas poisoning in many parts of the country during the past winter has called the attention of the public to the hazards involved in the improper use of gas. Several States have considered legislation limiting the use of gas for heating. In the city of Baltimore a considerable number of deaths occurred, and as a result the department of health undertook an investigation to determine the causes of these accidents. Because of the previous cooperation of the bureau in the Baltimore gas investigation it was requested to cooperate in the determination of carbon monoxide formed in various types of appliances. At the suggestion of the bureau the United States Public Health Service, the Bureau of Mines, and other agencies which were interested in similar problems were asked to cooperate in this investigation. Some members of the staff spent several months in field investigations and laboratory tests covering a large number of cases in which persons had been overcome by gas fumes. In a very large proportion of these cases it was found that appliances improperly designed or installed were responsible. This conclusion naturally led to the consideration of possible ordinances for controlling the sale and installation of appliances. In this connection information was collected from a large number of cities regarding their ordinances on the subject, and the bureau was represented on a committee of four which was charged with the duty of drafting ordinances for Baltimore.

Gas Safety Code.

Obviously the greater part of the work reported above has a direct bearing on the formulation of safety requirements to be observed in the use of gas. During the year committees of the American Gas Association have been actively at work in completing a new draft of the proposed National Gas Safety Code, for which the bureau and

the association are joint sponsors. This new draft is based largely on the preliminary version drawn up by the bureau. During the year the personnel of the sectional committee which is to consider this code has been approved by the American Engineering Standards Committee, and it is hoped that the two sponsors will soon be in position to submit a draft of the code to the sectional committee.

10. ELECTRICAL-SERVICE STANDARDS.

J. Franklin Meyer.

Standards for Electric Service.

For some years the bureau has been studying questions arising in connection with specifications for electric light and power service and the technical and engineering requirements that should be embodied by municipalities or by State public utility commissions in the ordinances, rules, and regulations promulgated by them. Public-service commissions in 40 States and in the District of Columbia are empowered by law to ascertain and fix adequate and reasonable standards for the measurement of quality and other conditions pertaining to the service rendered by public utilities and to prescribe reasonable regulations for examination and testing of such product or service and for its measurement.

A new edition of Circular 56, "Standards for Electric Service," originally published in 1916, was completed during the year and includes new laws, new and amended rules, and a more extended discussion of the engineering features of electric service regulation. It is, therefore, an exhaustive summary of the technical and engineering features of electric service regulation by commissions and municipalities. The revised (second) edition of the circular is now in press and it is expected will be published in the near future.

Street Lighting Service (Duncombe).

Many requests for information are received from municipal engineers and city electricians with reference to street-lighting problems. For some years the bureau has collected information, contracts, and engineering data on street lighting and has made suggestions in numerous street-lighting negotiations between municipalities and electric light and power companies.

An exhaustive survey of street-lighting practice and service conditions is actively under way, and the bureau is having the hearty cooperation of operating companies, municipalities, and manufacturers of street-lighting equipment. This study will cover the operating, engineering, illuminating, and contract aspects of street-lighting service throughout the United States.

Electrical Standardization.

The chief of this section has for some years been a member of the standards committee of the American Institute of Electrical Engineers and has recently been named to represent the bureau on the United States National Committee of the International Electrotechnical Commission. The bureau has several investigations under way in cooperation with the institute, and there has been the fullest cooperation throughout the year. A translation of the 1922 edition of the standards of the institute has been undertaken at the request

of the standards committee, and a first draft has been completed. The translation is now being revised and criticized by Spanish-speaking engineers in Cuba, South America, and in Spain.

As chairman of a working committee of the institute on graphical symbols the chief of this section presented to the standards committee an exhaustive report on electrical symbols.

In connection with the work of the American Engineering Standards Committee he has also served on committees on the Code for Electricity Meters, recently approved as an American standard, and on a committee having in hand an extensive program of standardization of symbols and abbreviations in engineering and science.

II. TELEPHONE SERVICE STANDARDS.

F. A. Wolff.

Quantity and Quality of Telephone Service.

The primary function of this section is the determination of measures for both quantity and quality of telephone service suitable for general adoption as standards. In order to fulfill this function it is necessary to acquire a comprehensive understanding of the fundamental scientific and engineering principles underlying the telephone art, as well as a thorough knowledge of the operating characteristics of all kinds of telephone apparatus and line construction and of the varying details of telephone practice in the United States. These, in turn, involve the collection and recording of a large amount of data. The most important data not yet fully collected and studied relate to the many more or less indefinite quantity units now in use and to the many characteristics of telephone service by means of which its quality is judged. A large amount of this kind of data has, however, been obtained through work done by the section acting in an advisory capacity to the General Supply Committee, which is responsible for the Government telephone service contract for each fiscal year.

This contract now includes many definitions of quantities, and each year it is made more accurate and more complete. As a result of this work misunderstandings and controversies have been greatly reduced and most harmonious relations with the local telephone company have been established.

General Survey of the Government's Telephone Facilities (Brown, Shoemaker, Bailey).

The systematic collection of the field data required to continue the normal work of the telephone section has been somewhat interrupted because of the important duties undertaken by this section at the request of the Bureau of the Budget. These required the making of a survey of all Government telephone service in the District of Columbia, with a view to effecting economy. In this work the section acted as the representative of the Budget Bureau and reported to the chief coordinator, General Supply.

Economies totaling over \$62,000 per annum have been effected without either curtailing or degrading the service. Most of this economy has been effected by increasing the efficiency of utilization of facilities, some by obtaining more equitable rates where large usage is involved, some by increasing operating efficiency through

consolidation of operating loads, and some by enabling proper checking of bills.

Further economies of any considerable magnitude depend largely upon reduction in operating costs, now totaling more than \$150,000 per annum. Studies have been begun to determine the extent to which operating costs can be reduced by substituting automatic switching equipment for manual switching equipment. There are some lines of work in progress in connection with the survey which will yield economies that are difficult to evaluate. For example, replacement of some 60 different voucher forms by one standard form and the introduction of uniform systems of keeping records of facilities are being considered.

The results of the survey in the District of Columbia have been considered so satisfactory by the chief coordinator that similar surveys have been ordered for Baltimore, Philadelphia, New York, and Boston. Considerable preliminary work has been done in Baltimore.

Standard Specifications for Government Purchase of Telephone Equipment.

A committee of departmental representatives, of which the chief of this section is chairman, was appointed by the Federal Specifications Board to consider the matter of standard specifications for Government purchase of telephone equipment. A preliminary meeting of this committee disclosed the facts that the Federal Government is not only one of the largest subscribers for telephone service, but also a large owner and operator of small telephone systems serving its peculiar needs in many locations. Both of these conditions make it desirable for the Government to carry on such work as the bureau is doing.

Telephone Transmission (Beltz, Sasuly).

Considerable progress has been made in the preparation of material for publication on the subject of telephone transmission. It will set forth the underlying principles involved in telephone transmission and their application to the predetermination of the transmission equivalent to telephone circuits as a whole, or of parts of circuits, in terms of the electrical constants thereof, and will facilitate the interpretation of transmission differences met in practice. The work has involved a careful digest of available literature on the subject and the presentation of the subject in the simplest form consistent with the inherent difficulties of the subject.

Submarine Cable Theory (Sasuly).

The material previously prepared on submarine cable problems has been rounded out during the year. A solution has been obtained in the form of a sequence of iterated functions, of the system of "chain" equations associated with this problem, as well as with the series-shunt networks of filter circuits. The scope of a paper by Moulton on the mathematical theory underlying the problem was broadened by correlating it with one of his papers of similar but more fundamental nature, prepared for the Ordnance Department, United States Army. The material affords a treatment of the theory more powerful and complete than any so far published.

Standard Cells (Shoemaker, Bailey).

There were tested for parties outside the bureau 187 standard cells. Of these 25 were from Federal and State institutions, and 162 were submitted by commercial concerns. In addition, 155 cells were checked for other sections of the bureau.

12. ELECTROCHEMISTRY.

G. W. Vinal.

Tests of Batteries (Schrodt, Snyder).

During the fiscal year 40 tests of a routine nature have been made comprising 332 batteries, including dry cells, flashlight batteries, radio batteries, storage batteries for starting and lighting service, airplane ignition and cranking batteries, hand lantern batteries, mine lamp batteries, and two forms of alkaline batteries. Tests were made for the Panama Canal, Department of Commerce, Signal Corps, Quartermaster Corps, Post Office Department, General Supply Committee, and Bureau of Aeronautics. In addition to the routine tests, a number of special tests have been made to obtain information desired for the preparation of specifications and other purposes. In addition to those mentioned above, 301 batteries have been included in these special tests. Among the more important of the tests made the following may be mentioned: The retest of several different makes of starting and lighting batteries which had failed on previous tests, delayed service tests on dry cells of foreign manufacture, tests of thin plate batteries designed for use on airplanes, comparison of alkaline storage batteries of American and foreign manufacture. The conference test of dry cells described in a preceding report has been completed.

Interlaboratory comparisons on testing methods and results have been made with a number of different manufacturers. In general, good agreement has been found between the results obtained at the Bureau of Standards and elsewhere, but in one significant case where large differences were found the fact was established that the bureau's results were correct.

Summaries of all dry cell tests for the past three years have been prepared and sent to the manufacturers, each manufacturer receiving information concerning the results on his own product.

Properties of Dry Cells.

The second edition of Circular 79 on the Electrical Characteristics and Testing of Dry Cells has been completed and published after very careful revision. The specifications for dry cells included in Circular 79 have now been adopted by the Federal Specifications Board and issued separately as Bureau of Standards Circular No. 139, United States Government Specifications for Dry Cells.

Experiments are in progress to obtain the necessary information for the standardization of dry cells for use on the filament circuit of vacuum tubes. A number of different tests are being made to develop the physical characteristics of these batteries.

Specifications for Storage Batteries and Sulphuric Acid.

On request of the Federal Specifications Board the preparation of specifications for various types of storage batteries is to be under-

taken, and preliminary arrangements have been made in the formation of a committee to handle this subject.

Work is also under way on the formulation of specifications for sulphuric acid. Data have been collected on the heat of dilution, contraction, specific heats, viscosities, electrochemical equivalents, freezing points, and the permissible amounts of certain impurities. Available books published on the subject of sulphuric acid have been reviewed, and a visit has been made to one manufacturing plant where particulars relating to the manufacture and transportation of the acid were studied.

Airplane Batteries (Snyder).

An investigation has been in progress throughout most of the year on airplane storage batteries submitted by the Navy Department with a view to developing characteristics of thin plate batteries, including the relation of capacity and rate of discharge, temperature, life, weight, and volume. This investigation is about 50 per cent completed, and preliminary reports have been submitted to the Navy Department. Preliminary specifications for airplane batteries were also prepared at the request of the Navy Department. These specifications are to be revised upon completion of the tests now in progress.

Impurities in Storage-Battery Electrolytes (Altrup).

An investigation of the effect of impurities in storage-battery electrolytes has been in progress throughout the year. The first part of this investigation was on a method for determining the rate of sulphation of storage-battery plates. Since local action occurring at the plates results in a change in weight, it was found possible to make an accurate determination of the local action by weighing the plates when suspended in the acid. The results of this part of the investigation have been published. The second part of the investigation related to a study of the effect of iron, copper, platinum, and manganese. This has been completed and a paper prepared for publication. Reports on this investigation have also been rendered to the Bureau of Engineering, Navy Department, at whose request the investigation was undertaken.

Jelly Electrolytes.

A short investigation was made on the preparation and properties of jelly electrolytes for storage batteries. The results confirmed the previous opinion that the use of jelly electrolytes is not desirable in storage batteries, but it was necessary to carry out this work in order to answer the numerous inquiries received and to fill certain batteries submitted by the Bureau of Aeronautics of the Navy Department in accordance with their request.

Patent Electrolytes.

Preliminary steps have been taken in an investigation of patent electrolytes. A summary has been prepared, and all available information, including analyses of these materials made by various storage-battery companies, is being collected. In a few cases experiments have been made at the bureau.

It is intended that this work shall supplement and extend the work now being done in studying the effect of impurities in storage-

battery solutions. From the information which has been gathered it is apparent that most of the patent electrolytes contain substances which may be harmful to storage batteries. In other cases the added materials are useless. These materials are sold with extravagant and impossible claims at relatively high prices.

Lead-Antimony Alloys for Batteries.

A study of the physical properties of lead-antimony alloys which are used for storage-battery grids was undertaken in connection with the investigation of the physical performance of airplane batteries for the Bureau of Aeronautics, Navy Department. Casting of alloys of various compositions were made by the metallurgical division, and measurements of density and expansivity of the specimens were made by the division of weights and measures. Measurements of the resistivity were made by this division and other factors by the metallurgical division. The work was correlated and the report prepared by this section. The report has been submitted to the Bureau of Aeronautics and will later be prepared for publication.

Porosity of Storage-Battery Plates (Altrup).

A preliminary investigation was made to find a suitable method of measuring the porosity of storage-battery plates. Two methods were employed, one based on calculations from the weight of the plates dry and the other on water absorption. Before the first method could be satisfactorily used it was necessary to devise a method for drying the negative plates, since these are subject to rapid oxidation in the air. It was found that these could be satisfactorily washed in distilled water and dried in a vacuum, the resulting plate having a blue color quite unlike the gray color which the negative plates ordinarily have. The results obtained by the two methods were in good agreement, but the work is not considered completed.

Storage-Battery Separators (Holler, Snyder).

An investigation of storage-battery separators has been made in connection with the investigation of the physical performance of batteries for the Bureau of Aeronautics. A method was devised for measuring the resistance of individual separators when immersed in the electrolytes. Measurements of the electrical resistance and mechanical properties of these separators, as affected by time of immersion, concentration, temperature, figure, thickness of the back web, method of cutting, and method of treatment, have been made on 85 different samples of various kinds of wood obtained from three manufacturers. A full report on this subject has been prepared for the Bureau of Aeronautics and will be prepared also for publication. Information on separators has been furnished also to the Bureau of Engineering, Navy Department, and the Motor Transport Division of the War Department.

Rectifiers (Holler, Schrodtt).

A preliminary investigation of rectifiers for battery charging has been made. This investigation included experiments on aluminum and tantalum rectifiers of the electrolytic type, two forms of the gas-filled bulb type and five varieties of the mechanical type. The object of the tests was to determine the efficiency, power factor, cur-

rent, energy capacity, and life. Oscillograph measurements of the impressed voltages and the alternating and rectified currents were made by means of an oscillograph. The outline of a proposed circular on rectifiers has been prepared.

Crank-Shaft Acceleration (Snyder).

As an outgrowth of work on batteries for starting airplane engines, an investigation was undertaken at the request of the Army Air Service to determine the crank-shaft acceleration of a 12-cylinder Liberty airplane engine during the starting period. Measurements of the displacement of the shaft were made by means of an oscillograph and a specially designed commutator, and from the records obtained the velocity and acceleration of the shaft, both with and without ignition, could be computed. From an analysis of the engine conditions significant points on the curves could be explained, and a record of the cylinders which fired, missed, and back fired could also be derived.

Detarnishing of Silver (Schramm).

An extended investigation was made on the tarnishing and detarnishing of silver at the request of the Office of Home Economics, Department of Agriculture. The first part of the investigation consisted in a study of the causes of tarnishing, the preparation of a standard tarnish, weight of the tarnish film, and a determination of the factors which accelerate and retard tarnishing. The second part of the investigation consisted of a study of the methods of detarnishing, with especial reference to the electrolytic method, the formation of moss silver, and a comparison of the losses of silver occurring when the electrolytic method is used as compared with chemical and abrasive methods. This investigation was completed and a report was prepared and sent to the Department of Agriculture on February 15, 1923. A paper on this subject was presented to the Philosophical Society of Washington, January 27, 1923. The bureau has received numerous requests for the publication of the results of this investigation, and it is expected that the report will be shortened and prepared for publication during the early part of the coming fiscal year.

In connection with the above investigation a study was made of the effect of various samples of paper used for wrapping silverware on the tarnishing of specimens of pure silver and sterling silver. This investigation was made at the request of and in cooperation with the paper section of the structural, engineering, and miscellaneous materials division. A large number of specimens were wrapped with samples of paper furnished by the paper section, and they have been allowed to stand, some in a moist atmosphere and some in a dry atmosphere, for a period of nine months. It is expected to terminate the experiment at the end of a year from the date on which it was started.

Cooperation with Outside Committees.

Assistance has been rendered through service on various committees dealing with battery problems. The questions considered have included railway batteries and storage batteries for automotive purposes.

The customary assistance has been rendered to the General Supply Committee in the award of contracts for dry cells and flashlight batteries. A table has been prepared showing the proper lamps to be used with various sizes of flashlight batteries.

13. RADIOACTIVITY AND X-RAY MEASUREMENTS.

W. H. Wadleigh.

General Testing (Torrey).

The functions of this section include measurement and certification of radium and mesothorium preparations and self-luminous surfaces and materials, measurement (without certification) of the radioactivity of weakly radioactive solids, slimes, waters, solutions, and other preparations for developmental, experimental, and commercial purposes, and measurement of the protective coefficients (efficiencies) of X-ray protective materials.

The growth of this work is illustrated by the following table, which shows approximately the amounts of material certified as a result of gamma-ray tests during the past nine and one-half years.

Year.	Number of preparations.	Equivalent milligrams of radium.	Year.	Number of preparations.	Equivalent milligrams of radium.
1914 (half year).....	28	486	1918-19.....	474	13,159
1914-15.....	82	2,097	1919-20.....	1,240	25,278
1915-16.....	112	4,531	1920-21.....	2,129	35,565
1916-17.....	223	6,638	1921-22.....	2,120	32,044
1917-18.....	177	5,376	1922-23.....	2,163	24,172

Of the 2,163 preparations certified this year, 7 were reported to be mesothorium equivalent in activity, as measured, to 449 milligrams of radium. During the year there has developed among physicians and radiologists a decided tendency toward the use of smaller radium preparations, but in larger numbers. This has meant that the considerable decrease in the amount of radium received for test has not brought any appreciable decrease in the number of tests called for nor in the amount of work to be done.

In addition to the above eight miscellaneous tests of ores and commercial preparations for medical and experimental purposes were made during the year, and one standard solution of radium was furnished to the Bureau of Chemistry of the Department of Agriculture. One thousand two hundred and eighty-one samples of self-luminous materials and three of X-ray protective materials were also tested.

Emanation Measurements.

In March the measurement of emanation with the new Spindler and Hoyer electroscope was commenced. By making possible the measurement of smaller preparations than is possible by the gamma-ray method, this method opens the way to the production of small radioactive standards in solution for the use of scientific laboratories. The method also makes possible more accurate tests of radio-

active ore samples, a few of which have been included under the above-mentioned miscellaneous tests, but have thus far been tested by the alpha-ray method only.

Standards and Standardization.

During the year one 50-milligram preparation was added by purchase to the bureau's list of radium standards and has been carefully compared with the primary standard radium No. 6. Careful measurements and comparisons of all the bureau's other secondary radium standards with radium No. 6 have also been made, and it is proposed to send one or more of these in the near future to Madame Curie's laboratory, to the British National Physical Laboratory, and possibly to other European laboratories for recomparison.

Absorption Measurements.

During the fall and winter a series of measurements was made of the gamma-ray absorption coefficients of various noncorrosive alloys now being used in the manufacture of radium needles by the several radium-producing companies.

Carnotite Mines Survey (Wadleigh).

In July a brief survey was made of the carnotite mines of Colorado, and information was obtained as to the extent and location of these radioactive ores and the methods used in mining and reduction of the ores.

Public Health Service Investigation.

Since January, 1922, the section has been cooperating with the research department of the Public Health Service in an attempt to determine more definitely the kind and extent of the effects of the radiation from radioactive materials on the various members of the staff. It has been found that both low blood pressure and low leucocyte-blood content result from continued exposure.

PUBLICATIONS.

The following papers relating to the work of the electrical division have appeared during the year among the publications of the Bureau of Standards:

- The theory, construction, and use of the photometric integrating sphere (E. B. Rosa and A. H. Taylor), Sci. Paper No. 447.
- Radio-frequency amplifiers (P. D. Lowell), Sci. Paper No. 449.
- An electron-tube amplifier using 60-cycle alternating current to supply power for the filaments and plates (P. D. Lowell), Sci. Paper No. 450.
- Tables for the calculation of the inductance of circular coils of rectangular cross section (F. W. Grover), Sci. Paper No. 455.
- Apparatus for the determination of the magnetic properties of short bars (M. F. Fischer), Sci. Paper No. 458.
- Preparation and properties of pure iron alloys: II. Magnetic properties of iron-carbon alloys as affected by heat treatment and carbon content (W. L. Cheney), Sci. Paper No. 463.
- Formulas and tables for the calculation of the inductance of coils of polygonal form (F. W. Grover), Sci. Paper No. 468.
- Directive radio transmission on a wave length of 10 meters (F. W. Dunmore and F. H. Engel), Sci. Paper No. 469.
- A method for the accurate measurement of short time intervals (H. L. Curtis and R. C. Duncan), Sci. Paper No. 470.

- Methods of measurement of properties of electrical insulating materials (J. H. Dellinger and J. L. Preston), Sci. Paper No. 471.
- Alternating current resistance and inductance of single-layer coils (C. N. Hickman), Sci. Paper No. 472.
- United States Government Specifications for dry cells, Circular No. 139.
- Properties of electrical insulating materials of the laminated phenol-methylene type (J. H. Dellinger), Tech. Paper No. 216.
- Magnetic susceptibility and iron content of cast red brass (L. H. Marshall and R. L. Sanford), Tech. Paper No. 221.
- Relative usefulness of gases of different heating value and adjustments of burners for changes in heating value and specific gravity (W. M. Berry, I. V. Brumbaugh, J. H. Eiseman, G. F. Moulton, and G. B. Shawn), Tech. Paper No. 222.
- A new method for determining the rate of sulphation of storage-battery plates (G. W. Vinal and L. M. Ritchie), Tech. Paper No. 225.
- United States Government Specifications for large tungsten filament incandescent electric lamps, Circular No. 13 (tenth edition).
- Electrical characteristics and testing of dry cells, Circular No. 79 (second edition).
- Construction and operation of a two-circuit radio receiving equipment with crystal detector, Circular No. 121.
- Description and operation of an electron-tube detector unit for simple radio receiving outfits, Circular No. 133.
- Auxiliary condensers and loading coil used with simple homemade radio receiving outfits, Circular No. 137.
- A decimal classification of radio subjects—an extension of the Dewey system, Circular No. 138.
- Description and operation of an audio-frequency amplifier unit for simple radio receiving outfits, Circular No. 141.
- National safety code for the protection of the heads and eyes of industrial workers, Handbook No. 2 (second edition).

The following mimeographed letter circulars were prepared:

- No. 40. Radio publications of the Bureau of Standards. (Revisions of November 25, 1922, and May 1, 1923.)
- No. 46. Description of fixed condensers used with simple homemade radio receiving sets. (Superseded by Circular No. 137.)
- No. 47. Description of a loading coil used with simple radio receiving sets. (Superseded by Circular No. 137.)
- No. 48. Description and operation of an electron-tube detector unit. (Superseded by Circular 133.)
- No. 49. Description and operation of an audio-frequency amplifier unit for simple radio receiving outfits. (Superseded by Circular 141.)
- No. 50. Bibliography of books and periodicals on tests, properties, and uses of electrical insulating materials.
- No. 51. List of the more important United States patents covering materials and methods of manufacture of insulating materials.
- No. 73. Fees for testing radio apparatus.
- No. 75. The secondary standardization of radio wave meters.
- No. 76. The standardization of inductors at radio frequencies.
- No. 77. The comparison of condensers at radio frequencies.
- No. 78. Design of a portable short-wave radio wave meter.
- No. 85. Fees for magnetic testing.
- No. 86. Methods of measuring voltage amplification of amplifiers.
- No. 87. Methods of measuring properties of electron tubes.
- No. 90. Tests of radio receiving sets. I.
- No. 92. Radio signals of standard frequency and their utilization.
- No. 93. Tests of radio receiving sets. II.

The papers listed below have appeared in current scientific and technical publications:

- The effect of gas-saving devices on the efficiency of burners and the completeness of combustion (G. F. Moulton), A. G. A. Monthly, July, 1922.
- Effect of B. t. u. on burner efficiency (reprinted from Tech. Paper No. 222), Gas Age Record 50; pp. 41-48, July 8; pp. 81-84, July 15; pp. 137-139, July 27, 1922.

- Bureau of Standards exhibit at American Gas Association convention (I. V. Brumbaugh), A. G. A. Monthly 5, No. 3, p. 167; March, 1923.
- State rules or laws governing the heating value of gas (reprinted from Circular 32), A. G. A. Monthly 5, No. 5, p. 317; May, 1923.
- The national electrical safety code and its relation to distribution (M. G. Lloyd), Safety Engineering 44, p. 22; July, 1922.
- The testing and use of magnetic compasses for airplanes (R. L. Sanford), Part II of Nat. Ad. Com. for Aeronautics, Report No. 128.
- Note on the development of an electron-tube amplifier which uses 60-cycle alternating current to supply power for the filaments and plates (P. D. Lowell), Jour. of the Amer. Inst. of Elec. Eng., 41, pp. 488-490; July, 1922.
- Some measurements of telephone sensitivity (H. H. Smith), Wireless Age, 9, p. 65; August, 1922.
- The effective capacity of pancake coils (G. Breit), Phil. Mag., 44, p. 729; October, 1922.
- A method for testing and rating electron-tube generators (L. M. Hull), Proc. I. R. E., 10, p. 373; October, 1922.
- The Bureau of Standards lends a hand (J. H. Dellinger), Radio Broadcast, 2, p. 40; November, 1922.
- A device for recording electric contact using an electron-tube generator and a radio-frequency spark (C. T. Zahn), Jour. Wash. Acad. Sci., 12, p. 412; November 4, 1922.
- A variable resistor of low value (C. N. Hickman), Jour. Opt. Soc. of Amer. and Rev. of Sci. Inst., 6, No. 8, p. 848; October, 1922.
- The electrical characteristics of dry cells (G. W. Vinal and L. M. Ritchie), Chem. and Met. Eng., 27, pp. 546 and 603; 1922.
- Method for determining the rate of sulphation of storage-battery plates (G. W. Vinal and L. M. Ritchie), Chem. and Met. Eng., 27, p. 1116; 1922. Elec. World, 80, p. 1386; 1922.
- Static electricity (F. B. Silsbee), Tech. Rev. Nat. Assoc. of Cleaners and Dyers, p. 173; November, 1922; p. 181, December, 1922.
- A direct reading and computing attachment for sphere photometers (B. S. Willis), Trans. Ill. Engrg. Soc., 18, No. 1, p. 62; 1923.
- The present status of commission regulation of electric light and power service (J. F. Meyer), Electric Light and Power, 1, No. 1, p. 21; January, 1923.
- Variation of metallic conductivity with electrostatic charge (F. Wenner and N. L. Forman), Phys. Rev., 20, No. 6, p. 589; December, 1922.
- The measurement of light (E. C. Crittenden), Jour. Wash. Acad. Sci., 13, No. 5, pp. 69-90; March, 1923.
- Experiments with the two-plate condenser antenna (J. C. Warner), Radio News, 4, p. 1618; 1923.
- The work of the International Union of Scientific Radio Telegraphy (J. H. Dellinger), Proc. Inst. Radio Engrs., 11, p. 75; April, 1923.
- A 100 to 3,000 meter oscillator (H. J. Walls), QST, 6, p. 48; May, 1923.
- The control of radio interference (J. H. Dellinger), Lefax, 13, p. 22; March, 1923.
- Aircraft terminals and the aeronautical safety code (A. Halsted), Engineers and Engineering, 40, No. 2, pp. 43-45; February, 1923.
- Preparation of safety codes under the auspices of the American Engineering Standards Committee (M. G. Lloyd), Bulletin No. 333, Bureau of Labor Statistics, pp. 225-231; May, 1923.
- The development of industrial safety codes (M. G. Lloyd), Mechanical Engineering, 45, p. 356; June, 1923.
- Lead resistance for current transformers (F. B. Silsbee), Electrical World, 81, p. 1082; May 12, 1923.
- Continuous-wave radio transmission on a wave length of 100 meters using a special type of antenna (F. W. Dunmore), Proc. Inst. Radio Engineers, 11, p. 243; June, 1923.

The following papers are in press:

- Spectrum analysis of radio signals (C. Snow), Sci. Paper.
- Uniform safety legislation (editorial) (M. G. Lloyd), Mechanical Engineering, 45, p. 444; July, 1923.
- Nondestructive testing of steel hoisting rope (R. L. Sanford), Mining and Metallurgy; July, 1923.

- New developments in telemetric devices (O. S. Peters and R. S. Johnston), *Engineering News Record*.
- Résumé of rules used in electric light and power regulation (J. F. Meyer), *Electric Light and Power*, 1 No. 7, p. 41; July, 1923.
- A study of radio signal fading (J. H. Dellinger, L. E. Whittemore, and S. Kruse), *Sci. Paper and QST*.
- Recent developments in radio in the United States (J. H. Dellinger), *Bulletin of the Pan American Union*.
- Introduction to line radio communication. Signal Corps Radio Pamphlet.
- Formulas and tables for the calculation and design of single-layer coils (F. W. Grover), *Jour. A. I. E. E.*
- Reducing the guesswork in tuning (J. H. Dellinger), *Radio Broadcast*.

HEAT AND POWER.

H. C. Dickinson.

FUNCTIONS.

The field of the division includes measurement of heat, temperatures, and the thermal properties of matter; the specific effects of temperature on materials of construction; the transmission of heat; the production of power by means of heat engines; and the properties of fuels, lubricants, and accessories essential to the production of power by this means. Some of the projects are: Establishment of the standard scales of temperature throughout the range of measurable temperatures; testing and standardization of thermometers, pyrometers, and other temperature-measuring instruments; determination of specific and latent heats, heats of reaction, melting and freezing points, and other properties of materials, in the determination of which precise heat measurements are the principal requirements; standardization of calorimeters; production and distribution of standard heat and temperature samples; industrial application of heat and temperature measurements; determination of fundamental engineering data involving thermal constants; determination of the fire-resistive properties of structural materials; measurements of power characteristics of aircraft and other automotive engines; efficiency of power transmission in vehicles; characteristics of cooling radiators, brake-lining material, and minor accessories; properties of liquid fuels as regards power production and economy; laws of lubrication and behavior of lubricants; and performance characteristics of automotive vehicles.

SECTIONS.

1. Thermometry.
2. Pyrometry.
3. Heat measurements.
4. -----
5. Cryogenic laboratory.
6. Fire resistance.
7. Automotive power plants.

GENERAL STATISTICS.

Staff	78
Expenditures (1922-23)	\$211,000
Tests completed	36,116
Researches completed	12
Bureau publications issued	6
Other technical publications	30

WORK CHART.

I. THERMOMETRY.

SCOPE.

Standardization of temperature scale below 500° C.

Testing of thermometers.

Miscellaneous temperature tests.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Laboratory thermometers.....	3,008	3,052
Clinical thermometers.....	15,085	26,953
Resistance thermometers and wire.....	29	17
Thermocouples.....	29	12
Thermohydrometers.....		122
Special tests.....		29

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Annealing of thermometers.....		Continuing.	
Standardization of industrial tests.....		Continuing.	

2. PYROMETRY.

A. High Temperature Measurements.

SCOPE.

Standardization of temperature scale above 500° C.

Testing pyrometers.

Development of pyrometers and methods.

Properties of materials at high temperatures: (a) Melting points, (b) Electrical resistance, (c) Specific heat.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Pyrometers.....	130	190
Melting points.....	36	67
Special.....	1	7
Thermoelectric analysis.....		114
Installations.....		3

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Standardization of temperature scale:			
Melting point of palladium.....		95	
Establishing purity of metals used for fixed points.....		50	
Development of optical pyrometer and micro-pyrometer of high precision.....		100	Outside. ¹

¹ Jour. Am. Opt. Society and Review of Scientific Instruments; 1923.

B. Atomic Properties.

SCOPE.

Study of atomic and molecular structure by measurement of energy required for the formation of ions, excitation of radiation and other types of electronic-atomic energy exchange.

Experimental tests of the theory of radiation.

Measurement of radiation beyond the range of spectroscopic methods.

Development of new methods of exciting radiation.

A correlation of experimental data and critical examination of their bearing on theories of atomic structure.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
The use of high frequency currents for exciting radiation.....		Continuing.	
Spark spectra and soft X-rays of alkali metals.....		75	Outside. ¹
Stages in the excitation of thallium.....		100	Do. ²
Stages in the excitation of molecular and atomic spectra of halides.....		25	Do. ³
Methods of exciting resonance radiation of high boiling point metals.....		Continuing.	

¹ Jour. Am. Opt. Soc., October, 1922.

² Jour. Am. Opt. Soc.; 1923.

³ Physical Review; 1923.

3. HEAT MEASUREMENTS.

SCOPE.

Calorimetry: (a) Combustion calorimetry. (b) Calorimetry of gases, (c) Specific and latent heats, etc.

Thermodynamic properties of fluids.

Heat transfer: (a) Thermal conductivity of materials, (b) Heat transfer at surfaces (c) Heat transfer through structures.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Gas calorimeters.....		1
Standard combustion samples.....	497	548
Insulating materials.....		7

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Specific volume of saturated ammonia vapor.....	100	S467.
Specific heat of superheated ammonia vapor.....	75	Outside. ¹
Specific volume of superheated ammonia vapor.....	50	
Correlation of ammonia data.....	50	
Ammonia tables.....	50	C142, M52, outside. ²
Calorimetry of saturated fluids.....	100	
Properties of saturated steam.....	20	Outside. ³
Heat transfer through building walls.....	50	Do. ⁴
Heat transfer through air spaces.....	20	
Thermal conductivity at high temperatures.....	40	

¹ Refrigerating Engineering, vol. 9, p. 1; 1922.² A. S. R. E., December, 1922.³ Mechanical Engineering, vol. 45, p. 168; 1923.⁴ Jour. A. S. H. and V. E., vol. 29, p. 69; 1923.

5. CRYOGENIC LABORATORY.

SCOPE.

Production of low temperatures for general use: (a) Carbon dioxide refrigerating plant, (b) Liquid air, (c) Liquid hydrogen.

TESTS.

Occasional tests of materials and apparatus at low temperatures, mostly in cooperation with other sections.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Development of equipment and methods:			
Production, analysis, and liquefaction of hydrogen.....	95	
Vacuum-walled containers of high insulating efficiency.....	80	
Reflection coefficients of metals for radiant heat.....	70	

6. FIRE RESISTANCE.

SCOPE.

Research on fire resistive properties of: (a) Building materials, (b) Building construction, (c) Building devices.

Standardization of fire tests: (a) Temperature measurements, (b) Investigation of building fires.

Standards of practice: (a) Fire regulations, (b) Safety codes, (c) Building codes, (d) Specifications.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Fire tests of materials.....	5	236
Fire tests of constructions.....	44	81
Fire tests of devices.....	4	2
Intensity of building fires.....	.....	3
Auxiliary strength, absorption, etc., tests.....	1,469	2,541

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Fire tests of concrete columns.....		90	Outside. ¹
Fire tests of brick walls.....		85	Do. ²
Fire tests of hollow tile.....	Hollow Build- ing Tile Assn.	50	Do. ³
Strength of materials at high temperatures.....		40	
Building exits.....		25	
Fire tests of insulated safes.....		20	
Fire tests of roofing materials.....		20	
Intensity and duration of fire.....		20	
Fire tests of partitions.....		10	

¹ Rock Products, vol. 26, No. 5, p. 1201, Mar. 10, 1923.² Engineering News Record, June 29, 1922.³ Jour. Am. Ceramic Soc., vol. 5, No. 11, p. 788, 1922; vol. 6, No. 6, p. 748, 1923.

7. AUTOMOTIVE POWER PLANTS.

SCOPE.

Investigation of scientific and technical problems connected with design, operation, and testing of internal-combustion engines and their accessories as applied to automotive purposes.

Investigation of qualities and characteristics of fuels.

Investigation of qualities and characteristics of lubricants.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Gasoline.....	42	104
Oil.....	859	1,132
Grease.....	5	
Special tests (vacuum distillation).....	33	39
Carbon deposits.....		663
Carbon removers and gasoline improvers.....	4	
Spark plug sets.....	16	24
Brake linings.....	55	90
Viscosity determinations.....	64	72
Demulsibility.....	29	8
Calibration of viscosimeter tubes.....	33	19

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Aviation engines:			
Packard No. 1551.....	Navy.....	100	Report.
Wright H-3.....	do.....	100	Do.
Lawrance.....	do.....	75	
Effect of changes in carburetor air temperature upon engine power.....	N. A. C. A.....	100	Outside. ¹
Effect of changes in air fuel ratio on engine performance.....		90	
Effect of changes in compression ratio on engine performance.....		100	Report.

¹N. A. C. A.

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Ignition:			
Standard spark gaps.....	Army.....	60	
Ignition systems.....	.....	50	
Problems of ignition.....	.....	50	
Carburetion:			
Fuel atomization in carburetors.....	.....	40	
Stromberg NA-U6.....	Army.....	1	
Stromberg NA-D6.....	do.....	1	
Metering characteristics of carburetors under altitude conditions.....	do.....	100	Report.
Fuels:	SAE, API, NAC.....		
Cooperative fuel investigation.....	.....	75	Outside. ¹
Dew points of hydrocarbon fuels.....	.....	95	
Fuels for high-compression engines.....	.....	75	Do. ²
Lubrication:			
Bearing friction.....	Army.....	50	
Low-temperature consistency of oils.....	do.....	80	
Oxidation of oils.....	do.....	50	
Lubrication under high unit pressure.....	.....	50	
Fractionation.....	.....	80	
Service tests.....	.....	40	
Transmission lubricant investigation.....	Army.....	20	
Viscosity of lubricants.....	.....	Continuing.	Do. ³
Improved MacMichael viscosimeter.....	.....	100	Do. ⁴
Saybolt universal viscosimeter.....	.....	45	
Bingham viscosimeter.....	.....	100	Do. ⁵
Reclamation of used petroleum lubricating oils.....	.....	90	T223.
Measurement of "Oiliness".....	.....	Continuing.	Outside. ⁶
Cooling problems:			
Air flow in confined spaces.....	Army.....	100	
Airplane radiators.....	do.....	60	
Air flow through radiators in flight.....	do.....	50	
Ballast recovery.....	Army.....	100	
Automobile brake linings.....	do.....	Continuing.	Report.
Truck rear axles.....	Army.....	100	Outside. ⁷
Combustion:			
Phenomena of combustion.....	N.A.A.S.P.....	25	
Combustion in engine cylinders.....	do.....	50	
Effect spark characteristics on combustion.....	do.....	100	
Miscellaneous:			
High-speed recording pressure indicator.....	.....	75	
Automobile headlight tests.....	.....	100	Do. ⁸
Testing catalytic agent.....	.....	50	
Auxiliary air valves.....	.....	50	
Effect of combustion chamber temperature on rate of carbon formation.....	.....	50	

¹ Jour. S. A. E., February, 1923; Jour. Ind. and Eng. Chem. May, 1923.² Jour. S. A. E., January, 1922; Jour. Ind. and Eng. Chem. May, 1923.³ Jour. Ind. and Eng. Chem. vol. 14, p. 715, 1922.⁴ Jour. Opt. Soc. of America, vol. 7, p. 335, 1923.⁵ Jour. Opt. Soc. of America, vol. 6, p. 875, 1922.⁶ Chem. and Met. Eng. vol. 28, p. 302, 1923.⁷ Jour. S. A. E., June, 1923.⁸ Automotive Industries, 1923.

Detailed Report of the Year's Work.

GENERAL.

The functions of the division are the maintenance of standards in the field of heat and temperature measurements, the establishment of basic data on the thermal properties of matter, and on the effects of temperature on materials of construction, and the investigation of materials and processes involved in the production of power by heat engines. For instance, the establishment of a standard working scale of temperature has been accomplished in the range of ordinary processes, but the extremely low and extremely high temperatures have yet to be covered.

This year has marked the completion of an investigation of the physical properties of ammonia which has resulted in what is probably more accurate knowledge of these properties than exists for any other substance. The results have been incorporated in a set of tables for the use of engineers.

The work in connection with problems of power production will probably result in a considerable increase in the available gasoline supply of the country, as well as a national improvement in materials used for brake linings on automobiles, thus bringing about an annual saving of millions of dollars to the users of motor vehicles.

Much of this work, in particular that pertaining to automotive power plants, fuels, and lubricants, has been conducted in close co-operation with the military branches of the Government, the American Petroleum Institute, the Society of Automotive Engineers, the National Automobile Chamber of Commerce, and the National Advisory Committee for Aeronautics. Many of these investigations are sponsored directly by the engineering division of the Air Service, McCook Field, Dayton, Ohio, the motor transport division of the Quartermaster Corps of the Army, or by the Bureau of Aeronautics of the Navy Department, and are supported in whole or in part by funds transferred from their appropriations under the terms of the appropriation statutes. In such cases results are reported direct to the sponsor and their publication is under its supervision.

I. THERMOMETER LABORATORY.

E. F. Mueller.

The greater part of the work of this laboratory is the routine testing of thermometers of various kinds. This is a basic and essential part of the service of the bureau to the scientific institutions and industrial laboratories of the country. Increase in the demands for work of this nature without a corresponding increase in the available personnel has made it impossible to perform the service as promptly as is desirable, and this condition should be improved. This work is at present substantially self-supporting.

The adoption of definite requirements for certification of thermometers and the issuing of reports for thermometers not eligible for certification has brought into prominence the fact that the certificates issued by the bureau are used rather as a basis for acceptance or rejection than for the purpose of obtaining higher accuracy in the use of the thermometers. Manufacturers are beginning to take an interest in the correctness of the tests made by the bureau and in their own tests, since failure to receive a certificate is a direct financial loss.

It will probably be necessary for the bureau to recognize, by revision in its testing procedure, that the industrial methods of using thermometers are essentially different from the methods used in a physical laboratory. The testing procedure at present in use is based upon the latter methods. At present a thermometer tested at 600° F. to an accuracy of 0.5° is likely to be used in a carefully standardized test in such a way that the results obtained are in error

by 20 or 25°. Such errors can be greatly reduced by use of suitable thermometers and methods of standardization.

The section has been represented on the American Society for Testing Materials committee on thermometers. The work of this committee will lead to simplification and greater accuracy in temperature measurements incident to industrial testing.

2. HIGH TEMPERATURES.

Paul D. Foote.

Industrial Pyrometry (Fairchild).

The return of prosperity in the industries using high temperatures is demonstrated by the marked increase in the number of routine tests of pyrometers for the current year; also, the large increase in the number of consultations with technical engineers indicates that the industries are meeting competition by improved methods of temperature control. The section has devoted considerable time to these conferences and to further discussions by correspondence.

The field work has been limited to the inspection of local plants where three pyrometric installations were tested, and detailed information was given for the efficient use of the existing equipment.

A standard rare-metal thermocouple scale has been definitely established, and it is hoped to standardize base-metal couples through further research and cooperation with manufacturers and users.

The section is now able to supply industrial laboratories with small quantities of gold, silver, palladium, and platinum having a certified purity and melting point. This is in addition to the series of common metals, which are issued in large quantity and the sale of which has been placed on a routine basis.

A paper now in press describes a suitable design of optical pyrometers for industrial use, and a pamphlet in the nature of a primer on the elements of thermoelectric pyrometry has been prepared at the request of the American Society for Steel Treating. This is a much simpler discussion of thermoelectric pyrometry than the large treatise issued as Technologic Paper 170 and is intended, primarily, for the use of the actual operators of furnaces in steel plants. Chapters on pyrometry for two technical handbooks issued in the current year were prepared by members of the section.

Research in Pyrometry (Fairchild, Hoover, Peters, Schmitt).

Research has been directed, primarily, toward the establishing of a standard, easily reproducible, high-temperature scale. This involves extensive investigation of the methods for producing and working metals of exceedingly high purity, means for maintaining high temperatures, and the determination of melting points. The investigation of the melting point of palladium, begun several years ago, has been practically completed. The value found for this fixed point on the high-temperature scale is 1,553.3° C., which may be changed by possibly 0.5° when the final series of measurements are completed.

A complete report on research in the design of optical pyrometers during the past three years will appear in the July, 1923, issue of

the Journal of the Optical Society of America and Review of Scientific Instruments. Thorough consideration of the optics of the pyrometer have suggested various designs which are free from the errors usually inherent in this class of optical instrument, and now temperature measurements may be carried out with a precision of 0.1°C . at $1,500^{\circ}\text{C}$.

The investigation of thermoelectric methods for the determination of small impurities in metals has been continued, in cooperation with the chemical and metallurgical divisions. The thermoelectric properties of a series of alloys are being studied, the work at present covering alloys of gold and palladium. The results are of especial interest, since for the first time, apparently, attention has been given to the securing of metal having extremely high purity. In this way the thermoelectric diagrams may be extended to alloys of only 0.001 per cent of the one metal. Such diagrams may prove of importance in a physical interpretation of thermoelectric phenomena.

As a result of the work of the bureau in the preparation of platinum, spectroscopically pure, the design of a new type of mounting for a resistance thermometer was deemed advisable. The platinum wire is wound on a pure porcelain frame, thus removing dangers from contamination by traces of iron present in mica. Greater constancy at high temperatures has been demonstrated, and further work is now in progress.

Atomic Properties (Foote, Mohler, Ruark).

While speculations on the constitution of matter may seem far removed from applied science, yet the establishment by mathematical and experimental means of a sound theory of atomic structure would be of immediate practical value in the whole range of technical research. Thus, the publication in 1922, by the Danish physicist Bohr, of an extensive theory of atomic structure has justified an emphasis on experimental work planned, primarily, to test these conclusions. The most direct experimental tests are measurements of the energy required for the different types of atomic disruption (ionization), and the study of the spectra of the resulting radiations, work which has been in progress for five years. The measurement of radiations, beyond the range of spectroscopy, by electrical methods has been continued and the technique improved. Several methods of exciting radiation have been developed, such as the use of high-frequency current for producing discharges in gas at low pressure. A study of stages of excitation of some polyatomic molecules gave results having direct bearing on electron affinity.

In addition to the publication and presentation of these researches before scientific societies a book has been published in which a general view of the entire subject is given. In "Origin of spectra" the experimental results obtained in this and related fields of research on atomic structure are critically examined and summarized. The object has been to present the experimental data quite completely and to give the theoretical basis essential for an understanding of the experimental work. This attempt to coordinate the data and theories has been favorably received by both physicists and chemists.

3. HEAT MEASUREMENTS.

E. F. Mueller.

Thermodynamic Properties of Ammonia.

Practically all the measurements required for the preparation of tables of the thermodynamic properties of ammonia were completed during the fiscal year 1921-22.

The preparation of papers describing the experimental work and the computation of tables have occupied a large part of the present year.

Specific volume of superheated ammonia vapor (Meyers, Jessup).—The only experimental work on ammonia still under way consists in some further measurements of the specific volume of superheated vapor. A higher precision in these measurements than was required for the preparation of tables appears desirable because such precise measurements, combined with the data on specific heat, may afford decisive tests of the validity of equations of state.

Specific volume of saturated ammonia vapor (Cragoe).—The manuscript of a paper on the specific volume of saturated ammonia vapor was completed and the paper published. The experimental work had been completed several years ago. A paper on composition, purification, and certain constants of ammonia, prepared several years ago in the division of chemistry, was edited and has been published.

Flow calorimeter (Osborne, Stimson, Sligh, Cragoe).—Manuscripts of two papers describing the flow calorimeter used for measuring the specific heat of gases and the measurements on the specific heat of ammonia vapor, respectively, were nearly completed.

Data on ammonia, ammonia tables, and Mollier chart (Van Dusen, Cragoe, Meyers, Jessup).—The correlation of all of the data obtained in the bureau's investigations on ammonia, by means of a suitable system of equations, was successfully accomplished, but the material has not yet been prepared for publication.

Ammonia tables, based on the system of equations mentioned above, have been computed in the foot-pound Fahrenheit system of units used by refrigerating engineers in this country. A preliminary edition was published in December, 1922, and the final edition in April, 1923.

A new Mollier chart for ammonia, representing the data in the tables of the preceding paragraph, was drawn and published.

Properties of Steam (Osborne, Stimson).

The general outline of this problem was given in considerable detail in the report for the preceding year. Much careful work in the design and testing of component parts of the apparatus to be used has been completed, and the work is progressing about as anticipated.

A paper on the calorimetry of saturated fluids, which outlines the general program for the investigation of the properties of steam, has been submitted for publication.

Heat Transmission and Thermal Conductivity (Van Dusen, Finkelstein).

Measurements by means of the conductimeter were made of the heat transmission through a number of types of building walls, including brick, hollow tile, concrete block, and the ordinary construction with wood joists. It is expected that results will be available during the next fiscal year.

A large number of preliminary experiments dealing with the transfer of heat across air spaces have been made, and apparatus has been designed and is under construction for continuing these measurements under more favorable conditions.

Miscellaneous.

Owing to other demands, very little, except a few routine tests and some construction work on the apparatus for measurements at high temperatures, has been done in connection with the measurement of thermal conductivity.

In gas calorimetry and combustion calorimetry only a small amount of routine work has been done.

5. CRYOGENIC LABORATORY.

C. W. Kanolt.

Liquid Air Plant (Cook).

The liquid air plant supplies the demand for liquid air for other divisions of the bureau and occasionally for outside institutions. It is operated on one or two days each week, producing from 15 to 20 liters at each operation. Much of this supply is required by other laboratories of the bureau.

Carbon Dioxide Plant (Cook).

The carbon dioxide refrigerating plant is operated mainly to supply refrigeration for researches of the heat division, and less frequently for use in the testing of aviation and other instruments at low temperatures by the division of mechanics and sound. The cryogenic laboratory also has cooperated with various sections of the bureau in a number of miscellaneous projects requiring low temperatures.

Special Vacuum-Walled Containers (Kanolt).

One project of the section has been the development of special vacuum walled containers of very high heat insulating value for retaining liquified gases with a minimum loss and for other purposes requiring such containers. Work on this project was described in the last annual report, since which further progress has been made in the perfection of these containers. In connection with this work apparatus has been developed for determining the coefficients of reflection of metals for radiant heat.

Liquid Hydrogen (Kanolt, Cook).

The operation of the liquid hydrogen plant has been placed on a satisfactory basis, and there is now no difficulty in producing liquid or solid hydrogen when required. The liquefier produces about 2 liters per hour.

Considerable attention has been given to the purity of the hydrogen. Very small quantities of nitrogen or oxygen in the gaseous hydrogen used will cause rapid clogging of the small hydrogen expansion valve with solid nitrogen or oxygen. In other laboratories the hydrogen has been purified by cooling with liquid hydrogen prepared previously. The practice at the bureau is to make very pure hydrogen electrolytically without other purification than the relatively simple processes of removing oxygen by heat and water by calcium chloride, and carefully avoiding contamination of this hydrogen by traces of air. The locating and eliminating of sources of contamination have been facilitated by the development of an analytical method for determining nitrogen in hydrogen by which very small quantities can be detected and measured. Since pure hydrogen has been made available in this way no trouble has been experienced from clogging of the liquefier.

6. FIRE-RESISTIVE PROPERTIES OF BUILDING MATERIALS.

S. H. Ingberg.

Fire Tests of Brick Walls (Ingberg, Newcomer).

The fire tests of brick walls described in previous reports have been concluded, so far as they concern fire tests and fire and water tests of restrained and unrestrained panels. A further series of fire tests under load is contemplated for which equipment is being provided. In the fire tests walls 11 feet high and 16 feet long are subjected to the standard fire test for periods up to six hours. The conclusions from the fire tests conducted this year confirm those from previous tests relative to the adequacy of the various types of brick walls under fire conditions. In the fire and water tests the walls are subjected to the standard fire exposure for one hour, when a hose stream is applied for five minutes to the side exposed to fire. Hollow and solid masonry of the same general thicknesses and made of the various kinds of brick used in the fire tests withstood the fire and water tests without serious impairment. Tests of specimens of masonry laid at the same time as the fire-test panels and of specimens cut from the walls after fire test give a measure of the loss of strength due to fire exposure. The concluding fire tests under working load will be on walls made of brick that sustained the highest losses in strength in this series to determine definitely ability to support working load under fire conditions.

Hollow Tile Investigation (Foster).

In the investigation of the fire-resistive and other properties of hollow building tile, conducted in cooperation with the Hollow Building Tile Association, 56 fire tests of tile masonry 4 feet square have been made, comprising a series to determine (1) the effect on fire resistive properties of adding ground burnt clay (grog) to the raw clay, (2) the protection afforded by various plaster coatings, (3) the effect of fineness of grinding of the raw clay, (4) the influence of shape and size of unit, (5) the effect of adding a combustible filler to the raw clay, and (6) effect of wall thickness. Some of these investigations have been completed and the results published. Freezing and thawing tests and compressive strength and absorption de-

terminations have been made of tile representative of those used in the fire tests. Chemical and mineralogical analyses have been made of nearly all clays represented and work begun on the determination of the thermal expansivities of the burned clays, these determinations being made in cooperation with other divisions.

Standardization and Interpretation of Fire Tests.

Experiments are being conducted to obtain information on the intensity and duration of typical building fires. A one-story brick and concrete building 16 by 30 feet has been constructed, which, by the use of discarded furniture, etc., can be fitted to represent typical occupancies, such as an office, a storage room, etc. Fire is started either at one spot, or over a considerable area, and the intensity and duration of the fire are observed by means of temperature measurements at a large number of points. Three such tests were completed. Information of the kind furnished by the tests is necessary for the proper interpretation of the results of fire tests of materials and constructions.

Theater Curtains (Ingberg, Mitchell).

An investigation of the fire resistance and general adequacy of theater fire curtains was begun at the request of the Commissioners of the District of Columbia. The program includes fire and operation tests of several types of curtains, as well as investigation of possible improvements in design.

Building and Safety Codes.

Tentative building-exit codes for schools, factories, and mercantile establishments have been drafted by a sectional committee of the American Engineering Standards Committee, on which the section is represented, and several proposed building and safety codes have been reviewed.

New Investigations.

New investigations which have been planned and on which some of the preliminary work has been done include fire tests of light interior partitions, fire tests of insulated safes, and fire tests of roofing. Equipment for tests of strength of materials at high temperatures is complete, and work on this subject is to be resumed.

Fire Tests of Concrete Columns (Hull).

Fire tests of about 90 reinforced concrete columns were made at the former Pittsburgh testing station. The report of this work is nearly ready for publication.

Miscellaneous Fire-Resistance Activities.

Among miscellaneous activities may be mentioned tests of the safety of operation of motion-picture projectors and inclosing booths, made at the request of other Government departments, an investigation on the merits of a proposed plan to increase the fire resistance of the mansion house and adjacent buildings at Mount Vernon by filling the wall spaces in whole or part with mineral wool, an investigation of the cause of the fire in the Treasury Building on May 3, 1922, and the preparation of a circular on the fire resistive properties of building materials for the use of the United States Chamber of Commerce in its program to reduce the national fire waste.

7. AUTOMOTIVE POWER PLANTS, FUELS, AND LUBRICANTS.

W. S. James.

Altitude Laboratory (Sparrow).

Engine performance.—One of the important projects of the section is the study of performance of aircraft engines as affected by altitude. During the year reports have been submitted to the Bureau of Aeronautics of the Navy Department, covering very complete performance tests of two aircraft engines—the Packard 1551 and the Wright H-3. These engines were tested in the altitude chamber according to a test program of broad scope, including changes in compression ratio. The results constitute a comprehensive analysis of the behavior of these two types of engines under all normal conditions met with in flight. Although neither of these reports has been published, as they comprise special work for the Navy Department, they have been circulated to a considerable extent among aviation engine builders.

Effect of air temperatures.—When aircraft or other such engines are run at various temperatures of the intake air the power developed varies with the temperature. To make such results comparable, it is necessary to know the exact effect of air temperature on the power output of the engine.

An investigation of this question has been completed, the report prepared, and submitted to the engineering division of the Air Service. The report has now been submitted to the National Advisory Committee for Aeronautics for publication.

Mixture ratios.—The performance of internal-combustion engines is markedly affected by the proportions of air and gasoline supplied to it by the carburetor. An investigation of this subject has been made and a report prepared for submission to the National Advisory Committee for Aeronautics.

At the request of the American Chemical Society a paper entitled "Fuel requirements of internal-combustion engines" was prepared for and presented at the New Haven meeting of that society.

Ignition (Silsbee).

Ignition problems have been handled jointly by this section and the electrical division and have consisted mainly of certain specific investigations requested by the Air Service and the National Advisory Committee for Aeronautics.

Size of spark.—It is sometimes claimed that an intense or "hot" spark will cause the explosive mixture in an engine cylinder to burn more rapidly, and hence give more power than when a weak ignition spark is used. An extended investigation has been carried on to determine whether or not such a connection between the spark and the rate of burning exists. The results indicate that for mixtures of several explosive gases and also for gasoline vapor mixtures no such effect exists, and that the combustion initiated by the weakest spark which can ignite the mixture at all will give as rapid burning as will an igniting spark many times as intense. This study has now been completed and a report will be submitted to the National Advisory Committee for Aeronautics shortly.

Spark gaps.—At the request of the Air Service a study has been initiated of the various possible types of spark gap used in testing

ignition apparatus. The best types of gap now in use are quite erratic and it is desirable to standardize on the one which under test shows the greatest permanency and the least variation of sparking voltage with external conditions.

Special tests.—In order to obtain more definite knowledge of the electrical phenomena which occur when an ignition system functions and to correlate the output of such apparatus with their design, a comparative study of 10 radically different types of magnetos and spark coils has been started. It is hoped that the results will be of assistance to the manufacturers of such devices in improving their design and to the purchasers in adopting proper specifications and methods of test.

While the bureau can not at present make routine tests of ignition apparatus for the public, a number of sets of spark plugs have been examined and tested from Government departments, municipalities, and from manufacturers whose products have shown sufficient originality to warrant making tests for the information of the bureau.

Carburetion (Sparrow, Cummings, Castleman, James).

Aircraft.—Flight tests of a radial air-cooled aircraft engine have shown such peculiar carburetor characteristics at varying altitudes that the Bureau of Aeronautics of the Navy Department requested tests in the altitude chamber to determine the reasons for this erratic behavior. Tests have been completed with this engine fitted with two different types of carburetors. As similar tests of the performance of carburetors at varying altitudes have been made during the year with two types of carburetor on a Packard 1551 aircraft engine and with three types on a Wright H-3 aircraft engine, information as to aircraft-engine carburetors has been materially increased.

Pulsating flow.—Although a great deal is known concerning the factors controlling the metering characteristics of carburetors when a steady stream of air flows through them, this condition is not met with in actual service on engines, as in this case the air flow is intermittent or pulsating. An investigation of the metering characteristics of several carburetors with both pulsating and steady air flows has been carried out for and reported to the engineering division of the Air Service.

Atomization.—In order to insure optimum conditions for complete and intimate mixing of the fuel and air in the intake manifold the fuel should be as minutely subdivided as possible. Vaporization of the fuel will, of course, result in the finest physical subdivision, but the attendant loss of power resulting from increased temperature of the mixture has made the possibilities of satisfactory mixing of finely atomized fuel and air of great interest. An investigation has been under way of the factors controlling (1) the formation of the liquid drops from jets issuing from orifices of various types and (2) the transportation of such drops in the air streams. This work will probably be completed during the coming year.

New facilities.—A new carburetor-testing plant for both automobile and aircraft carburetors has been designed and is in process of construction. This will have sufficient size and pump capacity to handle the largest airplane carburetors, and in many cases it will be

possible to test the complete intake system as a unit. The testing chamber is a reinforced monolithic concrete casting, and it will be possible to vary the temperature of the air supplied the carburetor from about -30 to $+80^{\circ}$ C. Three independent methods for the measurement of the quantity of air flowing through the carburetor and a device for the production of pulsations in the air stream are being provided.

Fuels for Internal Combustion Engines (Sparrow, Lee, Carlson, Kennedy).

Special aircraft fuels.—In order to prevent the destructive detonation resulting from the use of gasolines in high-compression aircraft engines benzol, alcohol, or other material must be blended with the gasoline in varying proportions, dependent upon the compression ratio and volumetric efficiency of the engine considered. A rather complete investigation of alcohol-gasoline and benzol-gasoline blends has been conducted, both as regards the physical and chemical characteristics of the blends and their performance in aircraft engines. During these tests an engine was operated with a compression ratio as high as 14 to 1. It is believed that this is the first time so high a ratio has been employed with an engine operating on the Otto cycle. Reports covering this work have been submitted to the Bureau of Aeronautics of the Navy. In addition, some of the outstanding results were presented at the winter meeting of the Society of Automotive Engineers in a paper entitled "Testing fuels for high-compression engines."

Economic motor fuel.—It is well known that a relatively small reduction in the volatility of motor gasoline will result in a significant increase in the quantity of gasoline which can be produced from a barrel of crude oil. The effect of such reduction in volatility upon the miles of transportation per gallon of gasoline possible with the existing motorized transportation equipment of the country has, however, been a much disputed question. During the past year, at the request of three national societies—the American Petroleum Institute, National Automobile Chamber of Commerce, and the Society of Automotive Engineers—representing the automotive and petroleum industries, the bureau undertook an investigation of this question. The work has been carried out in close cooperation with these organizations and so far has consisted of (1) two series of road tests—one under summer and the other under winter conditions, with cars estimated to represent approximately 75 per cent of the total number now in use, and (2) laboratory investigation with the engine of the car in most general use—to find the conditions under which differences in the fuels have a considerable effect upon engine performance and to evaluate the magnitude and importance of these differences.

Although the work is not yet completed, reports of its progress have been presented at the annual meetings of the American Petroleum Institute and the Society of Automotive Engineers.

Intake manifold temperatures.—The steady reduction in recent years of the volatility of motor gasolines available in this country has resulted in the general necessity for heating the explosive mixture in order to assist in vaporizing the fuel before its entry into the cylinders. As the power output of an engine is reduced when the

temperature of the explosive mixture in the intake manifold is heated, knowledge of the minimum temperature of the mixture at which the fuel will remain in the vapor phase is of practical interest. A method for the measurement of this temperature has been developed and applied to a number of gasolines. A publication giving the results of this work is in preparation.

Blended fuels.—In connection with the investigation on the physical properties of alcohol-gasoline blends for the Navy Department, a study has been made of the relations between the amount of water present in the alcohol and the temperatures at which separation of the alcohol and gasoline takes place. The results of this work have been reported to the Navy Department.

Lubrication.

Oxidation of oils (James, Sligh, Rade).—One of the most serious difficulties encountered in the operation of internal-combustion engines is the formation of so-called "carbon" deposits in the combustion chamber. Although a part of this "carbon" is due to road dirt and incompletely burned fuel, it has been found to vary with the character of oil used. It is at present believed that the deposits attributable to the oil are the result of its partial oxidation and may therefore be indicative of their rates of "carbonization" in service. During the past year, at the request of the Army Air Service, an investigation has been made of methods for the determination of the relative resistance of oils to partial oxidation similar to that previously proposed by Waters but more suitable for routine tests. A number of methods have been investigated and, although an entirely satisfactory one has not been completely developed, it is believed that this will be accomplished during the ensuing year.

"Carbon" deposits (James, King).—During the year there has been initiated an investigation of the conditions of engine operation which are of primary importance in controlling the formation of solids in the combustion chambers and crank cases of engines. Some qualitative data on the effect of temperature of the metal parts of the combustion chamber on the amount of "carbon" deposit formed have been obtained and made available to the automotive engineers through the trade press. It is believed that the results of the investigation when completed will be of great assistance in the interpretation of laboratory tests of engine lubricants in terms of their performance in use.

Service tests (Thorne).—In addition to the laboratory engine tests on lubricants, several tests have been made on fleets of vehicles in actual service. These "service" tests so far made have been for the purpose of developing a satisfactory procedure for such work. It is believed that such a procedure has been successfully developed, and comparisons between the performance of oils, differing in definite particulars, are contemplated during the coming year.

Gear lubrication (von Ammon).—The limited knowledge available in regard to the lubricants best suited for gear transmissions of automotive vehicles, involving the lubrication of both gears and bearings, has stood in the way of preparing satisfactory specifications for such lubricants. At the request of the Quartermaster General the bureau undertook to carry out an investigation of the more generally used transmission and bearing lubricants, including both the fluid and the semifluid types.

In view of the probable difference in the requirements of gears and antifriction bearings, it is necessary to study the problem of gear lubrication separately from the problem of antifriction-bearing lubrication. This and the need of ascertaining very small differences in friction losses and wear resulting from the use of different lubricants have called for the planning and preparation of much special test equipment, some of which has made necessary preliminary experimental work. It has for this reason not been possible so far to begin actual laboratory tests.

The operation of the specially designed apparatus for the investigation of journal-bearing lubrication has been carefully investigated and very materially improved during the year. Some serious difficulties have been encountered and overcome. Several series of runs have been obtained, during which it has been possible to obtain satisfactory readings considerably below the region of the minimum coefficient of friction. It is hoped that this investigation can be continued.

Low temperature effects (Griffin).—In the starting of aircraft engines under winter conditions the maintenance of an ample supply of oil to the rubbing surfaces is of great importance. The viscosity of aircraft oils is high, even at the normal operating temperatures, and when the oils are cooled to the temperatures encountered in winter it may be so great as to prevent the entrance of the oil into the suction side of the oil pumps. Of two oils of the same viscosity at the working temperature (200° F.), one from a naphthene and the other from a paraffine base, the pour test of the paraffine base oil due to the crystallization of the paraffine wax will be materially higher than that of the oil from the naphthene base, although the absolute viscosity of paraffine base oil at low temperatures will be considerably less than that of the naphthene base oil. The question as to the significance of the pour test in estimating the relative ease with which oils will be drawn into aircraft-engine oil pumps under winter conditions is therefore of importance. The engineering division of the Air Service requested the bureau to investigate this question, using aircraft oils from both naphthene and paraffine base crudes. This is being done by measuring the rate of oil flow into aircraft-engine oil pumps when operating at low temperatures and also by measuring the plasticity of the same oils at low temperatures. Apparatus has been designed and constructed for both parts of the investigation. It is planned to complete this investigation during the ensuing year.

Viscosity of lubricants (Herschel).—The viscosity of lubricating oils is generally recognized as being their most important characteristic. Recent demands for greater accuracy in the measurement of viscosity by means of the viscosimeter in most general use, the Saybolt Universal, have shown that its present state of standardization is inadequate. Considerable work has been done during the year to increase the accuracy of standardization of this instrument. This investigation has been carried out in close cooperation with the American Society for Testing Materials, the American Petroleum Institute, and the National Electric Light Association.

Reclamation of used petroleum lubricating oils (Herschel).—This investigation of the possibilities of reconditioning or reclaiming used petroleum lubricating oils, started last year, has been continued with special reference to automobile and steam turbine oils. Steam turbine oils are used continually for long periods of time—that is,

one or two years—while at present automobile oils are used only for a relatively short time and then discarded. The problem in the case of steam turbine oils is the original selection of oils which can be maintained in good condition the greatest length of time. In the case of the automobile oils the problem involves either the reconditioning of the oils while in use in the car or after draining from the crank case. In cases where the cost of collection is small—that is, in central garages caring for large number of vehicles—the possibilities of batch reclamation of crank-case drainings are promising.

“Oiliness” of lubricants (Herschel).—The property of “oiliness” of lubricants has been recognized as an important quality which has not yet been sufficiently defined to be capable of laboratory tests. A special friction-testing machine, modeled after that of Deeley, has been built for the study of this property, and its performance is being investigated.

Miscellaneous (James, Herschel).—An investigation has been made of several types of viscosimeters in which the action depends upon the viscous drag between two rotating cylinders immersed in the oil, the viscosity of which is to be determined.

Short investigations have been made of a test for the gum formation characteristics of gasoline proposed by the Bureau of Mines and of slight changes in the method of test for demulsibility of oils.

A condensed statement of the experience gained at the bureau in the engine testing of lubricants has been prepared and transmitted to the Bureau of Mines to assist them in a recently initiated investigation of the suitability of California oils for use in automotive engines.

Cooling Problems (Kohr, Harper, Butler, Zobel).

Aircraft radiators.—The application of the published results of the bureau’s comprehensive laboratory tests of the characteristics of aircraft radiators has been seriously hampered by the lack of information on the air flow through radiators in flight. In many airplanes the radiator is mounted in the nose of the fuselage or in other positions in which the air stream either entering or leaving the radiator is materially influenced by other parts of the airplane structure. An investigation of the air flow in flight through radiators mounted in this manner has been undertaken at the request and with the support of the National Advisory Committee for Aeronautics. A method has been developed for taking these measurements. The flight work is being carried out in cooperation with the flying personnel of the Bureau of Aeronautics of the Navy Department.

As the previous laboratory tests of aircraft radiator characteristics were carried out at maximum air speed of about 80 miles per hour, the National Advisory Committee for Aeronautics has requested that this work be extended to higher air speeds. The new wind tunnel equipment now available at the bureau has made it possible to take measurements up to air speeds of 150 miles per hour. This investigation will be completed during the coming year.

Measurements of air flow.—At the request and with the support of the National Advisory Committee for Aeronautics a critical study was undertaken of the behavior of Pitot tubes as used to measure the air flow through the cells of aircraft radiators. The subject has been

treated both from the theoretical and experimental standpoints with concordant results. The experimental work has been somewhat limited through lack of a wide range of types of core, although those used cover quite fully the small celled honeycomb type mostly used. A report of this investigation is being prepared for submission to the National Advisory Committee for Aeronautics.

Automobile Brake Linings (von Ammon).

An investigation of automobile brake linings which was begun about two years ago at the request and with the support of the motor transport division, Quartermaster Corps, has been continued. The bureau's earlier work stimulated manufacturers to more systematic investigation of the possibilities of improving their products, and that the efforts in this direction have borne fruit is shown by the further improvement found in many of the samples tested during the past year. This improvement is most marked in regard to the durability under severe service conditions which are accompanied by considerable increases in temperature. Some of the samples tested showed under these conditions a truly remarkable durability compared even with the improvement noted in the preceding year. The results further indicate that similar durability can be obtained not only in linings covering a fairly wide range of variety, quality, and staple of asbestos and percentage of cotton and wire but also with either of the two types of saturant in most general use, one of which is of asphaltic nature, while the other type is a rubber compound capable of vulcanizing.

New test equipment now being installed will aid materially in expediting the routine testing of the many new products being constantly submitted. It will also make possible the further development of additional tests planned earlier; of these an intermittent application test will, it is believed, prove of particular interest. An increasing interest in making laboratory tests of brake linings is noted among manufacturers of automotive vehicles.

Road Performance of Engines and Cars (James).

In the comparison between dynamometer and road performance of automobile and truck engines significant and apparently unexplainable differences are often evident. The reasons for these differences are probably not due to errors in the laboratory observations, but to a lack of definite information as to the conditions of operation encountered on the road, thus making reproduction of such conditions in the laboratory uncertain. To assist in obtaining quantitative information on this subject, the bureau has designed and constructed apparatus that can be installed on practically any passenger car and truck and which records autographically about 18 measurements giving the performance of the engine and car. Among these records are rate-of-gasoline consumption, power output, car speed, wind speed, wind direction, weight of air used by the engine, and temperatures of the cooling water and lubricants in the engine and transmission. The accuracy and reliability of the several measuring and recording devices is being carefully investigated, and it is believed that the practicability of the apparatus for the purpose desired has been demonstrated. This apparatus should furnish data of great value to car designers on the performance of their products.

Mechanical Efficiency of Truck Rear Axles (von Ammon).

An investigation of the relative merits of heavy duty truck axles of 5-ton rating and of various types begun earlier under the auspices of the motor transport division, Quartermaster Corps, has been concluded.

The results relating to the efficiency of power transmission of the axles tested over the whole range of speeds and power have been presented in a paper read before the Society of Automotive Engineers.

Phenomena of Combustion (Stevens).

The information at present available on the rates of flame propagation through explosive mixtures is very meager in comparison with the wide application of the combustion of explosive mixtures for the production of mechanical power.

As is well known, the thermal efficiency and power output of engines can be increased by increase in compression ratio, but so far this has been limited because of peculiar and harmful types of combustion resulting from this increase. An investigation of the fundamental factors controlling flame velocities in explosive mixtures was started about two years ago and has been continued during the past year at the request and with the support of the National Advisory Committee for Aeronautics. A new optical method of extreme simplicity and high accuracy described in a recent report to the National Advisory Committee for Aeronautics has been developed for this investigation. During the past year this method has been applied to the measurement of the flame velocities in mixtures of pure carbon monoxide and oxygen in varying proportions and with varying amounts of inert diluting gases present.

During the ensuing year it is thought that the method can be used in the study of the rates of flame propagation in explosive mixtures of more complex substances.

Miscellaneous (Sligh, Sparrow, James).

A high-speed recording pressure indicator has been designed and is now in progress of construction. This indicator, it is hoped, will make it possible to obtain pressure-time and pressure-volume indicator cards of high-speed engines with sufficient ease and rapidity to permit of such cards being taken as part of all engine tests. Accuracy, rapidity, and ease of operation have been the prime considerations. The design has been developed after much preliminary investigation regarding the action of the various elements entering into it.

In cooperation with the photometry section of this bureau, a series of public automobile headlight tests were run in order to determine the average operating conditions of head lamps in service.

Results of these tests indicate that a majority of such lamps are in imperfect focus, resulting in waste of light and dangerous glare. These data have been given wide publicity, and it seems that they will prove of great value in helping to bring about more general attention to this important question of safe headlighting.

Several tests have been made of devices supposed to affect combustion in the engine cylinder, such as coating the inside of the cylinder with a catalytic agent and the use of valves opening when the piston is at the lower position of the suction stroke.

A short series of tests of power output and fuel consumption have been made of a small model (0.7 horsepower) of a newly developed type of 2-cycle engine.

A recording decelerometer for the study and testing of braking systems has been designed and constructed. This instrument was demonstrated at the summer meeting of the Society of Automotive Engineers on a number of automobiles, including several fitted with four-wheel brakes.

INFORMATION, TESTS, AND PUBLICATIONS.

Information, Cooperation with Societies, etc.

An important part of the division's activities has consisted in furnishing information on scientific and technical subjects related to its work by extensive correspondence, reports, or directly to technical men visiting its several laboratories. Many of the requests for information relate to physical data which are readily accessible to anyone interested, but a considerable proportion relate to special equipment or information developed by the bureau and may require considerable investigation. Information has been given on such matters as the installation of a complete dynamometer equipment for engine testing, on equipment for testing brake linings, on a number of matters relating to fire protection and prevention.

Members of the division have cooperated in the activities of various scientific and technical societies and organizations, including: American Petroleum Institute, American Physical Society, American Society of Mechanical Engineers, American Society of Refrigerating Engineers, American Society for Testing Materials, American Society of Civil Engineers, American Ceramic Society, American Concrete Institute, National Crushed Stone Association, National Lumber Manufacturers Association, Prepared Roofing Association, United States Chamber of Commerce, Hollow Building Tile Association, Interdepartmental Committee on Petroleum Specifications, National Advisory Committee for Aeronautics, National Fire Protection Association, Optical Society of America, and the Society of Automotive Engineers.

The division has been actively represented in the committee work of several of these societies, notably the American Society for Testing Materials, the National Fire Protection Association, American Society for Steel Treating, National Research Council, International Union of Pure and Applied Physics, the American Society of Refrigerating Engineers, and the Society of Automotive Engineers. Numerous papers dealing with the work of the division have been presented before scientific and technical societies.

PUBLICATIONS.

The following publications relating to the work of the division have appeared during the year among the publications of the Bureau of Standards:

Composition, purification, and certain constants of ammonia (E. C. McKelvy and C. S. Taylor), *Sci. Papers*, 18, p. 655; 1923 (No. 465).
Specific volume of saturated ammonia vapor (C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor), *Sci. Papers*, 18, p. 707; 1923 (No. 467).

Radiators for aircraft engines (S. R. Parsons and D. R. Harper 3d), B. S. Tech. Paper No. 211; 1922.
Tables of thermodynamic properties of ammonia, B. S. Circular No. 142; 1923.
Mollier chart for ammonia. B. S. Misc. Pub. No. 52; 1923.
Reclamation of used petroleum lubricating oils (W. H. Herschel), B. S. Technologic Paper No. 223.

The papers listed below have appeared in current scientific and technical publications:

Thermometry, pyrometry and heat conductivity (G. K. Burgess and Paul D. Foote). A monograph published as a section of Standard Handbook for Electrical Engineers, fifth edition. (This article was completely rewritten for the fifth edition.)
The origin of spectra (Paul D. Foote and F. L. Mohler), 250 pp. Chemical Catalog Co., New York, Monograph of The American Chemical Society).
Pyrometry (Paul D. Foote, C. O. Fairchild, T. R. Harrison, and R. M. Wilhelm), pp. 409-472. Liddell's Handbook of Chemical Engineering, McGraw-Hill, New York.
Critical potentials of thallium vapor (F. L. Mohler, Paul D. Foote, and Arthur E. Ruark), Science 57 pp. 475-477; 1923.
A precise method of measuring small emfs and the change in thermoelectric power of tin at the melting point (T. R. Harrison and Paul D. Foote), J. O. S. A. and R. S. I. 7, pp. 389-398; 1932.
The D₂ Zeeman pattern for resonance radiation (Paul D. Foote, Arthur E. Ruark, and F. L. Mohler), J. O. S. A. and R. S. I. 7, pp. 415-417; 1923.
The steam research at the Bureau of Standards (N. S. Osborne), Mechanical Engineering, 45, p. 168; 1923.
Heat transmission through building structures (E. F. Mueller), Jour. Am. Soc. Heating and Ventilating Engineers, 29, p. 69; 1923.
A simple apparatus for comparing thermal conductivity of metals and very thin specimens of poor conductors (M. S. Van Dusen), Rev. of Sci. Insts., 6, p. 739; 1922.
A laboratory hypsometer (E. F. Mueller and T. S. Sligh, jr.) Rev. of Sci. Insts., 6, p. 958; 1922.
Note on platinum resistance thermometer construction (T. S. Sligh, jr.), Rev. of Sci. Insts., 7, p. 203; 1923.
Measurement of specific heat of superheated ammonia (bureau report to A. S. R. E.), Refrigerating Engineering, 9, p. 1; 1922.
Thermodynamics of ammonia compression (discussion, C. S. Cragoe), Ref. Eng., 9, p. 125; 1922.
Ammonia tables. Preliminary edition published separately by A. S. R. E., December; 1922.
Composition, purification, and certain constants of ammonia (E. C. McKelvy and C. S. Taylor), Ref. Eng., 9, p. 213; 1923. (Same as S465.)
Specific volume of saturated ammonia vapor (C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor), Ref. Eng., 9, p. 239; 1923. (Same as S467.)
Mollier charts (E. F. Mueller and C. H. Meyers), Ref. Eng., 9, p. 295; 1923.
Effectiveness of different methods of making absorption determinations as applied to hollow building tile (H. D. Foster), Jour. American Ceramic Society, 5, No. 11, p. 788; November, 1922.
Investigation of cause of fire on U. S. Treasury roof (N. D. Mitchell), Quarterly National Fire Protection Association, 16, No. 3, p. 255; January, 1923.
Fire tests of concrete protected and reinforced concrete building columns (S. H. Ingberg), Paper before National Crushed Stone Association. Rock Products, 26, No. 5, p. 120; March 10, 1923.
Capping for compression specimens (H. D. Foster), Jour. American Ceramic Society, 6, No. 5, p. 263; May, 1923.
The fire-resistive properties of gypsum (S. H. Ingberg), Proc. American Soc. for Testing Materials, 16; 1923.
Effect of grog addition on fire resistance of hollow tile (H. D. Foster), Jour. American Ceramic Society, 6, No. 6, p. 748; June, 1923.
Testing fuels for high-compression engines (S. M. Lee and S. W. Sparrow), Jour. of Soc. of Autom. Engrs.; January, 1922.
Economic motor fuel volatility (R. E. Carlson), Jour. of Soc. of Autom. Engrs.; February, 1923.

- An investigation of some heavy-duty truck drive axles (S. Von Ammon), Jour. of Soc. of Autom. Engrs.; June, 1923.
- Fuel requirements of internal combustion engines (S. W. Sparrow), Jour. Ind. and Engr. Chem.; May, 1923.
- Another ether-drift experiment (R. J. Kennedy), Physical Review; July, 1922.
- A device for logarithmic and semilogarithmic plotting and finding powers and exponentials (R. W. Castleman, jr.), Jour. O. S. O. A. and R. S. I., 7, No. 5; May, 1923.
- The use of multiplied pressures for automatic altitude adjustments (S. W. Sparrow), Tech. note of National Advisory Committee for Aeronautics.

The following papers are in press or have been submitted for publication:

- Disappearance of the filament and diffraction effects in improved forms of an optical pyrometer (C. O. Fairchild and W. H. Hoover). To appear in July issue of J. O. S. A. and R. S. I.
- Stages in the excitation of the spectra of thallium (F. L. Mohler and Arthur E. Ruark). To appear in J. O. S. A. and R. S. I.
- Calorimetry of saturated fluids (N. S. Osborne).
- Uses of the Mollier chart (C. H. Meyers).
- The fire-resisting properties of building materials and constructions (S. H. Ingberg), Circular, U. S. Chamber of Commerce.

REPORTS OF NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

- Constant pressure bomb (F. W. Stevens).
- Correcting horsepower to a standard temperature (S. W. Sparrow).
- Flash-over voltage of spark plugs at high altitudes (F. B. Silsbee).
- Sparking voltage of gaps with hot electrodes (F. B. Silsbee).
- Sparking voltage of spark plugs (F. B. Silsbee).
- Effect of spark character on flame velocity (D. W. Randolph and F. B. Silsbee).

Papers presented before scientific societies but not printed.

- The excitation of spark spectra of rubidium and caesium in a low voltage arc (F. L. Mohler, Paul D. Foote, Arthur E. Ruark, and C. C. Kiess), Washington meeting of Optical Society of America.
- Atomic structure from spectroscopic considerations (Paul D. Foote). Lecture before American Association for Advancement of Science and American Physical Society, Boston, December 28, 1923.
- Stages in the development of the iodine spectrum and related critical potentials (F. L. Mohler and Paul D. Foote), Boston meeting of American Physical Society.
- Pyrometry (H. M. Schmitt). Illustrated lecture before George Washington University Engineering Society. Awarded gold medal.
- The alchemist (Paul D. Foote). Illustrated lecture at Rochester before Rochester Sections of Optical Society of America and American Chemical Society and at Washington before Washington Philosophical Society.
- The change in viscosity of oils with the temperature (W. H. Herschel), Jour. Ind. and Eng. Chem., 14, p. 715; 1922.
- The drainage error in the Bingham viscosimeter (W. H. Herschel), Jour. Opt. Soc. of America, 6, p. 875; 1922.
- Testing oiliness by friction testing machines (W. H. Herschel), Chem. and Met. Eng., 28, p. 302; 1923.
- Friction testing of lubricating oils (W. H. Herschel), Chem. and Met. Eng., 28, p. 594; 1923.
- Testing lubricating oils for quality (W. H. Herschel), Proc. Eng. Soc. of Western Pennsylvania, 38, p. 503; 1923.
- The improved MacMichael viscosimeter (W. H. Herschel), Jour. Opt. Soc. of America, 7, p. 335; 1923.

OPTICS.

C. A. Skinner.

FUNCTIONS.

The work of the optical division includes: Radiation and absorption spectra, along with certain phases of qualitative and quantitative chemical analysis for which these are especially applicable, and the development of infra-red photography for astronomical observations and aviation purposes; investigations and tests involving measurements of polarized light and its application, especially in the testing, standardization, and technology of sugar, including the supervision of the sugar laboratories of the customs service; measurement of the factors which determine color, the optical transmissive and reflective properties of materials, and the color grading of light sources and materials; performance and development of optical instruments and materials, including refractive indices and dispersion measurements; the more general field of radiation, determination of the fundamental constants of radiation, the development of radiometric methods and instruments, and the determination of the emissive, reflective, and absorptive properties of materials for thermal radiation; testing of photographic materials and devices and general photographic investigations; application of the light wave as a standard unit for high precision length measurements and development of interference methods.

SECTIONS.

1. Spectroscopy.
2. Polarimetry.
3. Colorimetry.
4. Refractometry and optical instruments.
5. Radiometry.
6. -----
7. Photographic technology.
8. Interferometry.

GENERAL STATISTICS.

Staff	45
Expenditures (1922-23)	\$130,000
Tests completed	6,612
Researches completed	31
Bureau publications	12
Other technical publications	10

WORK CHART.

I. SPECTROSCOPY.

SCOPE.

Determination of standard wave lengths.
Description of emission spectra of the chemical elements.
Analysis of complex spectra.
Spectrochemical research and tests.
Preparation of spectrum tubes.
Cathodic deposition of metal mirrors.
Photographic emulsion investigations.
Photochemical study of light-sensitive materials.
Tests of photosensitizing dyes.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Spectrochemical analyses:		
Platinum metals and alloys	66	20
Iron and steel	5	9
Brass, bronze	19	35
Miscellaneous	125	150
Spectrum tubes:		
Mercury	8	6
Cadmium	8	10
Helium, neon	30	12
Photosensitizing dyes:		
Dicyanin	7	3
Kryptocyanin		1
Pinaflavol		1

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Determination of secondary standards in the visible and ultra-violet arc spectrum of iron.	Allegheny Observatory.	100	S 466.
Determination of secondary standards in the red and infra-red arc spectrum of iron.	100	
Standard wave lengths in the solar spectrum	Allegheny Observatory.	10	
Wave-length measurements in the arc spectra of gadolinium and dysprosium.	100	
Wave-length measurements in the spectrum of chlorine.	50	
Wave-length measurements in the spectrum of scandium.	100	
Wave-length measurements in the spectrum of columbium.	100	
Wave-length measurements longer than 5,500 Å in the spectra of the six platinum metals.	100	
Wave-length measurements in the arc spectrum of tantalum.	50	
Series regularities in the arc spectrum of chromium.	80	Outside. ¹ Do. ²
Series regularities in the arc spectrum of molybdenum.	100	
Regularities in the arc spectrum of iron	100	
Regularities in the arc spectrum of titanium	100	
Regularities in the arc spectrum of vanadium	100	
Regularities in the arc spectrum of scandium	100	
Regularities in the arc spectrum of zirconium	50	
Regularities in the arc spectrum of nickel and cobalt	75	
Regularities in the arc spectrum of six platinum metals.	10	
Practical spectrographic analysis	100	S444.
The physical basis of spectrochemical analysis	50	

¹ Science, 56, p. 666, December, 1922.

² Wash. Acad. Sci., 13, p. 243; 1923.

2. POLARIMETRY.

SCOPE.

Magneto and electro optics.
 Natural optical activity.
 Double refraction.
 Physicochemical properties of common sugars.
 Properties and structure of the rare sugars and associate compounds.
 Analysis of sugars and sugar products.
 Color and decolorization in technical sugar products.
 Utilization of nonsugars.
 Standardization of practice in sugar technology.
 Starches.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
White consumption sugars.....	1	1
Soft sugars.....	20	25
Saccharimeters.....	40	43
Quartz control plates.....	111	50
Miscellaneous.....	6	13
Annealing schedule and thermal effects.....	2	2
Polariscopic determinations.....	1,656	1,844
Moisture.....	695	739
Molasses analyses.....	24	51
Polariscopic tube-cover glasses.....	2,000	800

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Magnetic rotation of quartz.....		85	
Magnetic rotation of Fe, Ni, and Co.....		80	
Magnetic rotation of Fe; O system.....		80	
Magnetic rotation of $C_{12}H_{22}O_{11}$		50	
Specific rotation of sucrose.....		20	
Rotary dispersion of sugars.....		40	
Growing of doubly refracting crystals.....		30	
Development of zinc gallium vapor lamp.....		90	
Development of thallium vapor lamp.....		30	
Thermal effects in glass:			
(a) Changes caused by annealing.....		50	
(b) Changes caused by chilling.....		100	
(c) Hardening glass.....		10	
(d) Density changes.....		5	
Electric double refraction.....		5	
Saturation relations in sugar mixtures.....		97	
Invertase value of clergot constant.....		40	
Densities of invert sugar solutions and the contraction of sucrose upon inversion.....		80	
Determination of raffinose and sucrose in crude beet products without use of enzymes.....		30	
Preparation of levulose.....		70	
Refractive indices of sugar solutions.....		35	
The halogen-acetyl and nitro-acetyl derivatives of the sugars.....		75	
The penta-acetyl derivatives of d-glucose.....		10	
Moisture determination on soft sugars.....		60	
Moisture determination on molasses sirups, etc.....		10	
Ash determination in sugar products.....		20	
Decolorization of low-grade honey.....		50	
Methods of purification of sugars.....		15	
Comparative trichromatic and quantitative spectrophotometric analysis of technical sugar products.....		85	
A standard sugar color, its absorption spectrum, luminosity, and classification.....		75	
Quantitative spectro-photometric analysis of technical sugar products.....		50	

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
The absorption spectrum of soft sugars.....		75	
Comparative chemical and colorimetric analysis of various sugars: Tabulation of color, analytical values, sieve tests, and deductions based on observations.....		90	
Methods of concentrating and analysis of beet-sugar waste water.....		5	
Preparation of pure organic compounds from waste water.....		5	
Dry distillation process.....		5	
Résumé of patent literature.....		100	
Utilization of molasses—sugar recovery.....		15	
Hydrogen-ion concentration of soft sugars.....		100	
Titration curves and buffer action of soft sugar.....		2	
Moisture absorption and caking of white consumption sugars.....		3	
Development of mechanical plants:			
Semicommercial.....		50	
Development.....		50	
A new fixed point on the thermometric scale.....		95	
The structure of fucose.....		100	S459. Outside. ¹

¹ Jour. Bio. Chem., 54, p. 65, 1922 (September).

3. COLORIMETRY.

SCOPE.

Specification and standardization of colors—determination of: (a) The color characteristics of natural and artificial sources of light, (b) the properties of materials which determine their color.

Study of phenomena and laws of color vision.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Spectral transmission glass.....	18	17
Other materials.....	3	3
Dominant wave length, purity, brightness.....		2
Spectral reflection.....	2	3
Spectral energy distribution, color temperature.....	3	2
Optical instruments.....		2

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Spectrophotometric and spectroradiometric methods.....		50	S440.
Standard data on optical properties of materials which determine their color:			
Dyes.....	Department of Agriculture.	100	Do.
Do.....		5	
Glasses.....		75	
Enamels.....		100	Outside. ¹
Vegetable pigments.....	Department of Agriculture.	75	
Vegetable oils.....		90	
Other materials.....		10	

¹ Jour. Am. Cerm. Soc., vol. 6, No. 5, May, 1923.

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Visibility of radiant energy.....		100	
The photometry of incandescent sources by the method of rotatory dispersion.....		75	
Color temperature of artificial light sources.....		75	S 443.
Spectral distribution of energy from complete radiator tables and graphs.....		90	
Researches in color vision:			
Analysis of color stimulus in terms of dominant wave length purity and brightness.....	Munsell Color Co.	50	
Psychologic standard of "white" light.....		50	S 417.
Visibility of radiant energy.....		25	
Sensibilities of the eye—hue, saturation, brilliance.....		10	
The three fundamental excitations.....		5	
Color blindness.....		5	
Systems of material color standards.....		5	

4. REFRACTOMETRY AND OPTICAL INSTRUMENTS.

SCOPE.

Testing of optical glass.

Testing of optical systems.

Design of optical systems.

Testing of optical instruments.

Design of optical instruments.

Construction of optical components.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Determination of indices of refraction.....	68	111
Transmission of optical glass.....	6	42
Measurement of focal length.....	6	10
Measurement of aberrations.....	19	33
Refractometers standardized.....	7	7
Binoculars tested.....	1	10
Mirrors silvered.....	6	83
Miscellaneous.....	34	37

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Aberration of photographic lenses.....		90	
Design of telescopic systems.....		60	
Instrument design:			
Lens for camera obscura.....		100	
12-inch telescope objective.....		80	
Magnifying stereoscope.....		100	
Field telemeter.....		100	
Small camera obscura for Aberdeen.....	Army.....	75	Outside. ¹

¹ Jour. of Opt. Soc. of America, 6, (5), July, 1922.

5. RADIOMETRY.

SCOPE.

Determination of the fundamental constants of thermal radiation.

Development of instruments and methods of radiometry.

Investigation of the emissive, reflective, and absorptive properties of materials for thermal radiation.

Maintenance of glasses for protecting the eyes from injurious thermal radiation.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Eye protective glasses.....	84	32
Standards of radiation.....	5	10
Photoelectric cells.....	3	7
Quartz mercury therapeutic lamps.....	21	.....

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Photoelectrical investigations:			
Argentite.....		100	S446.
Bourmonite and pyrargyrite.....		100	S451
Halide salts of thallium, lead, and silver.....		100	S456
Various photoelectrical investigations.....		100	S462.
Further tests of stellar radiometers and some measurements of planetary radiation.....		50	S460.
Some new photo-electrical and thermo-electrical properties of molybdenite.....		50	
Thermocouple measurements of stellar and planetary radiation.....		100	Outside. ¹
Optical society report on the present status of stellar and planetary radiation.....		100	Do. ²
Some observations on the transformation of thermal radiation into electric current in molybdenite.....		50	Do. ³

¹ Popular Astronomy, February, 1923.

² Jour. Opt. Soc. of America, December, 1922.

³ Proc. Wash. Acad. of Sci., November, 1922; Jour. Opt. Soc., January, 1923.

7. PHOTOGRAPHIC TECHNOLOGY.

SCOPE.

Sensitometry.

Investigation of illumination in photography.

Photomechanical processes.

Applied photography.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Emulsion characteristics.....	120	92
Filter factors.....	40	30
Standard lamps.....	.....	3
Desensitizers.....	.....	3
Developers.....	12	.....
Requisitions for photographic service.....	2,050	1,960
Design:		
Automatic camera.....	1	1
Sensitometer.....	.....	1
Photometer.....	.....	1
Printer.....	.....	1

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Characteristics of developers.....		10	
Effect of color of illumination.....		10	
Photographic characteristics of silver chloride, bromide, iodide, and other sensitive salts.....		25	
Effects of charred paper on photographic plates.....		100	S454.
Investigation of failure of reciprocity law of exposure time and light intensity.....		25	
Effect of intermittent exposures.....		10	

8. INTERFEROMETRY.

SCOPE.

Thermal expansion.

Calibration of end standards.

Line standards.

Index of refraction.

Dimensional changes of materials.

Plane surfaces.

Accurate measurements of the size of miscellaneous small objects.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Thermal expansion.....	17	118
Calibration of end standards.....	223	44
Line standards ruled.....	6	15
Plane surfaces.....	4	12
Dimensional changes.....	250	100
Refractive index.....	18	5
Dental materials.....	4	.....

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Thermal expansion:			
Ceramic materials.....		100	
Fused quartz.....		50	
Porcelain and white-ware glaze.....		30	
Ruling of line standards.....		30	
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Detailed Report of the Year's Work.

GENERAL.

Outstanding Accomplishments.

From the large group of varied activities necessarily briefly described below certain accomplishments may be cited here which are of more than ordinary interest.

A number of the chemical elements have been brought into the spectral series class which have heretofore, because of their very complex spectra, eluded all attempts at correlation.

Experiments have been carried out which seem to corroborate earlier conjectures that the process of annealing glass is not merely one in which the mechanical stress is relieved, but perhaps primarily one which permits and facilitates the formation throughout of definite molecular aggregates which characterize well-annealed glass.

An interferometer method has been developed for measuring refractive indices of samples no larger than 4 by 4 by 4 millimeters to an accuracy of 1 part in 1,000,000, or to seven significant figures, thus affording an effective means for investigating optical homogeneity and chemical purity of materials, as also for calibrating standard refractive index samples.

Two instruments of importance in photometry and colorimetry have been completed, tested, and found to function satisfactorily. One embodies the application of the principle of rotatory dispersion in producing what is effectively a specifically variable blue filter for eliminating color difference in the photometry of different light sources, and the other is a very complete monochromatic colorimeter which matches given colors by a definite quantity of white plus a definite quantity of a pure spectral hue.

I. SPECTROSCOPY.

W. F. Meggers.

Standard Wave Lengths—Secondary Standards in the Visible and Ultra-Violet Arc Spectrum of Iron (Meggers, Kiess).

Many problems in metrology, optics, spectroscopy, and astrophysics require for their solution a satisfactory system of standard wave lengths. About a decade ago such a system of secondary standards derived from comparisons of iron lines with the fundamental standard—that is, the red radiation from cadmium—was adopted by the International Union for Cooperation in Solar Research. These standards included 86 wave lengths of lines emitted by an iron arc burning with a 6-millimeter electrode separation, the light being taken from an axial part of about 2 millimeters in the middle of the arc. Some of these wave lengths were later shown to be influenced by the operating conditions of the iron arc, and this led, in 1922, to the following recommendation by the International Astronomical Union: "In order to obtain lines of constant wave length, constant intensity distribution, and adapted to high orders of interference, the adoption is recommended of the Pfund arc operating between 110 and 250 volts, with 5 amperes or less, at a length of 12 to 15 millimeters used over a central zone at right angles to the axis of the arc, not to exceed 1 to 1.5 millimeters in width, and with an iron rod 6 to 7 millimeters in diameter as the upper pole and a bead of oxide of iron as the lower pole." In view of these changes in the source it became desirable to remeasure the entire system of standards. A new set of values comprising 160 lines distributed at intervals of 20 to 30 Ångstrom units ($1 \text{ Ångstrom unit} = 0.0000001 \text{ millimeter}$ between the ultra-violet ($3,271.002 \text{ Å}$) and the red

(6,677.994 Å) was carefully determined by direct comparison with the red radiation from a cadmium-vapor spectrum tube. In addition to improving the relative values of the secondary standards, this investigation indicates that the present international system is nearly 1 part in 1,000,000 too large in the longer wave lengths.

Secondary Standards in the Red and Infra-red Arc Spectrum of Iron (Meggers, Kiess).

The International Astronomical Union in 1922 also recommended that as the secondary standards of longer than 6,000 Å are all stable lines, and as the exposures with the above-mentioned arc may be rather long, the 6-millimeter, 6-ampere arc be retained for this region. Since no secondary iron standards greater than 6,750 Å existed, the problem of extending this system to longer waves was undertaken. Using the original iron arc, the wave lengths of 160 spectral lines between the green (5,434.525 Å) and infra-red (8,824.238 Å) were accurately measured in terms of the cadmium standard. For stable lines common to both ranges this last series of values is in good agreement with the first series described above. The precision attained in these wave-length measurements is of the order of 1 part in 5,000,000.

New Table of Solar Wave Lengths (Meggers, Kiess).

Quoting again from the report of the International Astronomical Union: "It is believed that the time has arrived for the determination of a series of solar wave lengths in the international system to serve as standards for a new table of solar wave lengths." The spectroscopy section of the Bureau of Standards has accordingly entered into a cooperative program of solar spectrum wave-length measurements with the Allegheny Observatory, of Pittsburgh, Pa. (Doctor Burns). The necessary equipment was assembled and observations were begun in June.

Investigation of Arc Spectra (Meggers, Kiess, Stimson).

The description of the longer wave portions of the standard arc spectra of the chemical elements, which has occupied the bureau's attention for the past seven years, has been continued. During the past year these investigations have covered the following chemical elements: Gadolinium, dysprosium, columbium, tantalum, scandium, platinum, palladium, rhodium, ruthenium, osmium, iridium, and chlorine. In each case hundreds of new spectral lines were discovered in the red and infra-red spectral regions, representing important additions to spectroscopic data. The results for gadolinium and dysprosium were published in Scientific Paper No. 466. The long wave-length data for the spectra of the platinum metals were completed, but publication will be deferred until the poorly observed shorter wave regions have been investigated. In the case of chlorine no spectral data existed either in the red and infra-red or in the ultra-violet. The deficiencies in the longer wave region were remedied by employing specially sensitized photographic plates, and in the shorter by exciting the spectrum of chlorine in a tube of fused quartz, which is transparent to ultra-violet. So far as modern photographic technique will permit, we have now investigated the long wave portions of the arc spectra of nearly all of the known chemical

elements. A similar investigation is planned on the longer wave portions of the spark spectra of the chemical elements.

Spectral Regularities (Kiess, Walters, Meggers).

The emission spectra of the chemical elements consist, as is well known, of characteristic sets of lines. For many years practical use has been made of such sets for the identification of chemical elements in laboratories and in stars, but the physical origin of the spectral lines has always been more or less of a mystery. The interrelation of the different lines in any one spectrum has been for nearly 40 years one of the major problems in spectroscopy. In the case of the simpler spectra, like those of atomic hydrogen, the alkali metals, and alkaline earths, certain numerical relations were early found to exist between all or most of the lines of any one spectrum. These studies were not very successful in solving the structure of the more complex spectra, chiefly because the description of these spectra was neither accurate nor extensive enough for the purpose. Standard wave lengths, remeasurement of most of the spectra in international Ångström units, and especially the extension at this bureau of spectral data to the longer wave lengths, have made it possible to bring much order out of what looked like chaos. During the past year significant spectral regularities were found in the arc spectra of chromium, molybdenum, iron, nickel, scandium, yttrium, titanium, zirconium, and vanadium. Now for the first time clues have been found to the physical structure of the spectra of one or more elements in each column of their periodic classification; for example, potassium, calcium, scandium, titanium, vanadium, chromium, manganese, and iron occupying the fourth row of the periodic table from Column I to Column VIII. Some of the above-mentioned results have already been published, others are in press, and the remainder are in preparation. Similar investigations on the arc spectra of cobalt, columbium, tantalum, the six platinum metals, tungsten, and uranium are now under way. The computational work involved in the analyses of these complicated spectra is enormous, and much remains to be done before any of the spectra are completely classified. In most cases the lines thus far allocated comprise the majority of the stronger lines in any one spectrum, but not more than 5 to 10 per cent of the total number (3,300 for molybdenum and about 5,000 for iron) listed in wave-length tables. The discovery of regularities in these complex spectra is fundamentally important and is of marked value in developing theories of radiation and atomic structure.

Spectro-Chemical Analyses (Meggers, Stimson, Kiess).

About 200 spectrographic analyses were made during the year on a large variety of materials, including pure metals and salts, steel, bronze, brass and platinum-metal alloys, electrolytes, storage-battery grids, glass, gelatine ash, ores, and minerals. Whenever possible the spectrographic results have been checked by standard chemical analyses, so that a correlation of the mixed spectra and the percentage composition could be made, thus furnishing a basis for quantitative analyses from spectrograms of similar materials received in the future. The spectrograph has successfully demonstrated its practical value in supplementing chemical methods of

analysis, and in certain cases it may replace the more tedious wet methods, both for qualitative and quantitative results. Scientific Paper No. 444, Practical Spectrographic Analysis, was issued on this subject.

2. POLARIMETRY.

F. J. Bates.

Utilization of Molasses—Patent Résumé (Bates, Geldard, Peters, Proffitt, Jackson).

The search of the United States and foreign patents on the first division of this problem, namely, the utilization of the nonsugars, has been completed, the results correlated, and a report prepared. The report classifies the patents according to the arts comprised within the field, discusses their relationships and general purposes, and gives a digest of development as seen through the patents. Generally each patent is abstracted with a short description and a copy of one or more of the drawings accompanying the original patent. It includes a very comprehensive index of the patentees and the subject matter of the patents.

The phases of the problem with which this circular deals are: The recovery and utilization of amines, ammonia, cyanides, nitrogenous nonsugars, potash and alkalies, and miscellaneous products, such as glycerine, esters, fatty acids, etc.

Utilization of Molasses—Experimental (Geldard).

In continuation of the program outlined in the last annual report, a laboratory has been constructed and completely equipped for research work on methods for the utilization of discard molasses and waste water from sugar factories.

A large sample of waste water from one of the beet-sugar factories was obtained, and preliminary work on the analysis, evaporation, and handling of the concentrated liquor has been completed. Following suggestions offered by the patent literature, methods have been successfully applied for the recovery of some of the valuable organic compounds and the inorganic salts which are to be found in beet molasses and waste water. In addition to this procedure, work will soon be started on processes of dry distillation, accompanied by a study of the distillation products and the factors which influence the increase or diminution in yield of those which are economically important.

Cooperation with United States Customs Laboratories (Snyder).

The bureau has continued to assist the Treasury Department in the maintenance and operation of its customs laboratories. During the past year over 1,800 exchange samples of raw sugar were tested, approximately 50 per cent being direct polariscopic determinations and the remainder tests for the percentage moisture in addition to the polariscope determination. The importance of these control analyses can not be overestimated. Excellent agreement has been obtained between the bureau and the several customs laboratories. The installation of the Baltimore laboratory has been completed, the cooperation between the bureau and the appraiser of merchandise and his staff having made this laboratory possible. Its com-

pleteness and flexibility make it admirably suited for the wide range of work incident to the appraisal of imported merchandise.

Crystallization (Bates, Phelps).

The delicate thermostatic control apparatus for growing large and perfect crystals mentioned in the last annual report has been kept in operation during the year. In addition, a room has been utilized which is located so far below the surface of the ground that the daily variations in temperature are entirely eliminated and the seasonal changes amount to only 3 or 4°. A number of crystallization experiments have been started under the very constant conditions obtaining in this room. Relatively large crystals have been obtained of many of the rare sugars produced at this bureau, some of which have not before been produced above a microscopic size. The crystallographic and optical properties of some of these sugars have never been studied owing to the impossibility of obtaining suitable crystals. In some of the sugars that have been studied by the bureau, notably levulose, crystallographic forms have been observed which have not heretofore been recorded.

In addition to the various sugars, crystals of Rochelle salt and of tartaric acid have been grown for the purpose of showing the asymmetric character of these crystals and were exhibited at the Pasteur celebration in New York.

As an important result of the bureau's work on crystals a method of identification of the various sugars is being developed, using the optical properties as determined by a petrographic microscope. The work is only in the preliminary stage, but even in that stage the method makes it relatively easy to distinguish between all of the 12 sugars that so far have been examined. The method is much shorter and quicker than the older chemical method and requires only an extremely minute quantity of the material, 1 milligram being ample. The method is being extended to other sugars, and the properties of all are being measured to a higher degree of precision.

Rotation and Rotatory-Dispersion of Sugars (Phelps).

Accurate measurements of the rotatory dispersion of the various sugars now being prepared at this bureau are under way. It has been found necessary to expend considerable time and effort to bring the samples of the sugars on hand to the high state of purity necessary to be in accord with the precision of the rotation measurements.

Numerous methods for the preparation of the rare sugars have been published, but, owing to the lack of accurate polarimetric measurements, serious difficulty has been encountered by scientific workers as well as manufacturers in using them. The work necessarily progresses slowly.

Adjustment and Standardization of Polariscopes and Saccharimeters (Phelps, Golden).

The work of adjusting and standardizing polariscopes and saccharimeters has been continued. A large proportion of the instruments sent to this bureau for test are old types, many having a different basis of calibration from the newer ones, indicating that the supply of new instruments is still insufficient to fill the needs of the industry, notwithstanding that several excellent types have been on the market for some time. The bureau is constantly called upon.

to furnish information regarding the use of these instruments and has continued to render valuable service to the sugar industry. During the year 43 instruments were adjusted and standardized.

Thermal Properties of Glass (Tool).

The problem of producing a homogeneous glass free from strain is a very important problem in the commercial production of this material, and the available scientific knowledge in this field is very insufficient. This lack of information is particularly noticeable regarding the proper methods for a stable, stress-free glass for optical and scientific purposes. The investigations carried out by the bureau during the past year show that in the temperature region where glass becomes practically rigid there is on cooling a very great evolution of heat, while on heating through this same region there is a corresponding heat absorption. An exothermic effect is also obtained on reheating a rapidly cooled glass through a slightly lower temperature range. In the process of annealing, altering the treatment by changing the treating temperature and period and the cooling rate greatly varies the magnitude of the heat-absorption effect, and in chilling the glass the exothermic effect on reheating is greatly increased by increasing these same factors. From the data obtained in these investigations it appears that glass held at any temperature approaches more or less rapidly a relatively stable condition for that temperature. It has also been found that non-uniformly cooled glasses, as in the case of molded articles, are inhomogeneous, since the conditions attained vary from point to point. In annealing, therefore, the glass should be preheated at temperatures which will insure the rapid establishment of homogeneity and then treated for a sufficient period at a lower temperature, not only to free it from strain, but also to create a condition relatively stable at ordinary temperatures. The results of these investigations are now ready for publication.

Double Refraction in Strained Materials (Tool).

Measurement on the double refraction of strained transparent media affords a means of determining the magnitude and distribution of the stresses present in the material. Such stresses may be the result of improper annealing, the application of external forces, or other causes. If the stresses are caused by external forces, the methods of measuring the double refraction effects are of value in optical stress analysis. Glass improperly annealed is affected adversely by the resulting stresses, and the only practical method for determining their presence is some test for double refraction. Methods suitable for such tests and stress analysis are being investigated with a view to their improvement.

Investigations completed during the year have shown that the performance of glass used in optical instruments is often unsatisfactory because of inhomogeneities due, among other causes, to the heat treatment previous to the final annealing of the product. Such inhomogeneities accompanied by variations in the refractive index, density, thermal expansivities, etc., cause irregular stress distributions which can be detected by double refraction measurements. The stresses under these conditions may be smaller than those under a symmetrical distribution, but much more harmful. Similar investi-

gations are being continued, and it is hoped eventually to establish standards for the fitness of glass for optical purposes. Much assistance in this work has been received from the optical glass and instruments sections of this bureau.

Refractometric Estimation of Solids (Jackson, Peters).

The total solid content of a pure sugar solution can be readily and accurately determined by measuring its refractive index and comparing the observation with a table of known indices. Thus, the fundamental prerequisite to this method of analysis is the establishment of the tables with accuracy. Available data are at present valid to the fourth decimal, while the requirements of industry include the fifth decimal. It is now proposed, in cooperation with another section of this bureau, to determine the values by means of the interferometer. Preliminary experiments have demonstrated the feasibility of this method. This investigation is being carried out in response to a request from a committee of the American Chemical Society.

Molasses and the Tariff (Jackson, Snyder).

With the introduction of the present tariff act, which for the first time places the appraisal of imported molasses on a scientific basis, the bureau was called upon to specify the methods of analysis. In the previous act the direct polarization was the basis of appraisal, but this method did not accurately show the sugar content. In the present act the duty is based on the total sugars, which is an absolute measure of the value of this product, but this necessitates a determination of the per cent sucrose as well as the per cent reducing sugars. At the request of the Treasury Department the bureau conducted an investigation on the various methods of analysis and as a result made recommendations to the Secretary of the above department as to those most satisfactory for this work. The sucrose is determined by a method developed and perfected by the bureau. The comparative results obtained between the bureau and the customs laboratories show excellent agreement.

Determination of Malic Acid in Maple Sugar Sand (Phelps).

At the request of investigators in the maple-sugar industry the bureau has undertaken to measure accurately the fundamental optical constants underlying a proposed method for the determination of malic acid in maple sugar sand. Maple sap contains considerable malic acid. In the process of making maple sugar and sirup this malic acid is precipitated as calcium malate which is technically known as maple sugar sand. Formerly this sand was thrown away but now is becoming one of the chief sources for the production of malic acid. The methods of analysis then are very important, not only to the maple-sugar industry of the United States but also to Canada. It is because of this fact that the bureau is sufficiently interested in the proposed method to undertake the precise determination of the fundamental rotation constants upon which the method is based. The work has been but recently started, and only a few sets of observations have been made.

Testing of Molasses, Sirups, etc. (Snyder).

The bureau continued to act as referee between buyers and sellers of molasses in important transactions, the bureau's analysis in each

case being the basis of settlement. During the year 36 such analyses were made. The study of new methods for analysis of these products has been continued.

The collaborative work on ash analysis of molasses and sirups for the Association of Official Agricultural Chemists has been practically completed. As a result of the work of the collaborators the referee of the above association recommended that the sulphate method of ash determination be discontinued, and that the direct incineration method be made official. The work of the calendar year consists of an exhaustive study of the methods of determining moisture in molasses and sirups. The bureau had already undertaken a comparative study of these methods, particularly with reference to the so-called soft sugars. Complete analytical data have been obtained on 25 representative samples comprising all grades of soft sugars from a number of refiners. A study of the rate of loss in moisture has led to the adoption of an arbitrary procedure which is capable of reproduction comparable with the precision of the methods of determining the other constituents. Complete curves for each sample show the loss of moisture for given conditions.

The work on ash determinations was taken up by the American Chemical Society at their fall meeting and a committee appointed to make a study of the subject. A member of the bureau was appointed on this committee, together with representatives from the various branches of the sugar industry. The bureau has the preliminary work well under way.

Polarimetric Analysis of Crude Beet Products (Jackson, Nowak).

In general, the crude products of the sugar industry contain other optically active materials in addition to sucrose. Under these circumstances sucrose may be accurately determined by the Clerget procedure provided the rotation of these substances remains unchanged during the analysis. In beet products, however, this constancy of rotation can not be maintained because of the nature of the impurities. Thus, there occurs in beet juices the sugar, raffinose, which, like sucrose, is hydrolyzed by acids and by enzymes to a sugar mixture which has a different rotation from the original sugar. There are, moreover, optically active nonsugars present, some of which change in rotation upon acidification. We thus have three or more unknown quantities, whereas the Clerget method of analysis supplies but two equations. In continuation of a previous study of the Clerget method of analysis the modifications necessary to the determination of sucrose and raffinose have been studied. Comparative analyses have been made of a number of samples of beet molasses by acid inversion, by neutral polarization, and by inversion with specific enzymes. Tables have been constructed indicating the proper constants to be used in computation.

Saturation Relations in Sugar Mixtures (Jackson, Silsbee).

The sugars, sucrose, dextrose, and levulose are the principal members of the sugar group occurring as commercial sirups. These sirups are, in general, concentrated to such a degree as to be saturated or, indeed, supersaturated with respect to one or more of the constituent sugars. An investigation has been brought to comple-

tion in which the concentrations of each sugar in these saturated sirups have been determined in pure solution and in solutions of the mixed sugars. Thus the influence of each sugar upon the solubilities of the others has been measured. The composition of a cane-sugar sirup of maximum solubility and the influence of changing temperature have been determined. The compositions of invert sugar solutions which are saturated with dextrose at various temperatures have been tabulated. Certain relations respecting the granulation of honey have been found. Methods of partial inversion of sucrose have been described. The manuscript describing these experiments has been prepared for publication.

Preparation of Levulose (Jackson, Silsbee).

Levulose is the sweetest member of the sugar group and in various forms plays an important part in adult human nutrition. On account of the extreme difficulty of preparation and high cost the pure substance is not available except in minute quantities. Further experiments have been made on the process of preparation from invert sugar, beet molasses, dahlias, and Jerusalem artichokes. The two last mentioned are potentially abundant sources of supply. The experiments of the past year have shown the feasibility of adequate production at relatively low cost. A particular study has been made of the final crystallization of the product.

Analysis of Sugar by Enzymes (Jackson, Silsbee).

Important methods of sugar analysis are made available by the specific action of enzymes (substances extracted from yeast by autolysis and subsequent dialysis). The enzyme "invertase" decomposes sucrose quantitatively into invert sugar. In order to utilize this reaction for quantitative analysis, the fundamental constant must be determined with the required precision. This constant represents the change in rotation of sucrose before and after inversion by invertase. Previous determinations of this constant have been considerably at variance with one another. During the past year many determinations have been made, and a provisional value has been found to be 132.0 at 20° C. A further study will be required to establish the constant with the necessary precision.

A constant in which the enzyme, melibiose, is involved is the change of rotation of the sugar, melibiose, before and after hydrolysis. This sugar is formed by the partial hydrolysis of raffinose, and its change of rotation is thus a direct measure of the percentage of raffinose. Preliminary values of this constant have been obtained.

Densities of Invert Sugar Solutions (Jackson, Silsbee).

Densimetric methods of analysis are extensively used in industrial and scientific sugar laboratories. At present most of the density determinations are expressed as "sucrose," principally for the reason that only those of sucrose have been precisely determined. During the past year the densities of invert sugar solutions have been determined by a picnometer method. Invert sugar has in each experiment been prepared by careful inversion of pure sucrose in the presence of a minute quantity of an inverting agent, a small correction being applied for the agent itself.

At various intervals of concentration the expansion coefficients between 20 and 40° C. have been determined. From the density

data obtained it has been possible to calculate the contraction in volume which cane sugar undergoes upon inversion. This investigation has been nearly completed.

Color Standardization of Commercial Sugars (Peters, Phelps, Bates).

Excellent progress has been made in developing a system of color grading of sugar products, using as a basis the photometric analysis of transparent solutions. At the same time it is realized that the industry is sorely in need of a system of color grading of the dry refined white and moist soft sugars without going through the additional painstaking labor of preparing transparent solutions.

Several grades of white refined sugars of various grain sizes have been examined by methods employing the principle of multireflection. The spectral distribution of these sugars was thus determined in several parts of the visible spectrum. However, the principle of multireflection can not be used in the determination of color qualities of the colored sugar products, so that a differently constructed reflectometer must be employed. Since many obstacles yet remain to be overcome in the perfection of a suitable reflectometer which will grade color for all white and soft sugars, recourse has been had to a system of color grading which depends on the preparation of solutions, with an acceptable degree of transparency, from technical sugar products of all grades. Only a mathematical scale of color grading can be considered, and yet its equivalent in color sensations must be visualized. The successive color steps, therefore, proceed on a uniform ratio intensifying absorption at all wave lengths in the same degree. The starting point is the best quality of white sugar. Intensification of absorption at a uniform mathematical ratio based on a little-known law leads to the creation of a yellow color sensation. These progressive, uniform ratios of color intensification automatically lead to a system of classes and subclasses which start with the finest quality of white sugar and end with the lowest quality of residual waste molasses. The color of all sugar products at any point of the visible spectrum is measured in terms of the spectral distribution of the fundamental white sugar with its color intensity "1." Thus, it became possible to establish the photometric negative logarithms by their equivalent—a standard sugar color unit. The term "color unit," while an old-time routine expression, has never before been defined with scientific accuracy, nor has color been classified on the basis of a first quality white sugar.

Color and the Manufacture of Sugar (Bates, Phelps, Peters).

Attention has already been directed to the prime importance of developing a method for the rapid and accurate measurement of color in the various steps involved in the manufacture of sugar and its by-products. The investigation of these closely related problems has been made possible by the application of the results achieved in the bureau's work on the measurement of color to the finished products. The fundamental principles involved have gradually been extended to include all the intermediate products of cane sugar in process of refining. Thus far the bureau has been unable to give a similar study to the products of the beet-sugar industry, but intends to do so at an early date.

The past year's work in this field has established the gratifying fact that the chemical method developed by the bureau for the preparation of impure nonsugar products for optical analysis has shown it is sufficiently flexible and accurate for the purposes desired. It is the residual waste products of the beet, as well as the cane industry, which particularly endanger the validity of the fundamental law upon which all color determinations ultimately rest. Reliable estimates of differences in color quantity as well as quality must be established by photometric principles, and it is believed that the special photometer developed by the bureau for the sugar industry will meet all the requirements of the situation. A number of modifications yet remain to be made on this instrument. Various light sources are also being investigated.

In view of the new facts which have been developed during the past year it has become more and more evident that certain aspects of color determination in technical sugar products can finally be perfected only by a transfer of the photometric investigation to the industrial sugar plants.

One of the interesting phases which has gradually revealed itself is the fact that photometry of turbid solutions may ultimately become of value in the estimation of technical refining qualities of raw material, entirely aside from any question of color.

Ultrafiltration (Peters, Phelps).

The effect of ultrafiltration upon the optical properties of solutions of technical sugar products has been studied. This research is one of the numerous aspects of the investigation on color and decolorization of technical sugar products. The purpose of ultrafiltration is the separation of colloidal coloring matter from the molecularly dispersed coloring matter. As only concentrated, almost saturated, solutions can be employed, a new technique is being developed, so that the time consumed in the operation will not be too excessive nor prohibitive. A preliminary note of the effect of ultrafiltration methods on the optical qualities of soft sugars of all grades available in the open market has already been given out to the industry.

The research was found essential for the reason that the effect of the colloidal coloring matter upon the final color in technical refining operations can be studied in no other manner in such detail. The problem has never had the attention which it merits, for the reason that the whole technique is laborious and time consuming in the extreme. It is confidently expected that this method of ultrafiltration will bring about a better insight into the difficult problem of the absorption of coloring substances by the decolorizing carbons.

Acidity Measurements of Sugars (Proffit).

The importance of the reaction, which may be defined as the intensity of acidity or alkalinity of any sugar product has long been recognized, but only in a very general way by both producer and technical consumer. All producers of either raw or refined sugar try to maintain their intermediate products (juices and sirups) nearly, but not exactly, neutral. Some of the reasons for the variations from neutrality are: At the temperatures used even a small amount of alkali in the presence of reducing sugars, which are always present in cane juice, will cause the development of excessive

amounts of color and of other troublesome impurities; while, on the other hand, the presence of even small traces of acid, which means that there are hydrogen ions in excess of hydroxyl ions, will cause a loss of some of the sugar by "inverting" it to glucose and levulose. Hence, the cane-sugar manufacturer carries his intermediate products slightly acid to avoid the greater evil—dark colors, etc. On the other hand, the beet-sugar manufacturer, whose juices usually contain very little of reducing sugars, keeps his products slightly alkaline to avoid inversion losses. This difference in handling during the process of manufacture results in slight differences in the reactions of the final products, so that certain technical consumers of refined sugar, as, for example, candy manufacturers, find that they have to modify their treatment of a sugar, as yet somewhat blindly, according to the source from which it comes. The importance of the reaction of a sugar as to its effect on the taste, on the ease of flocculation of impurities in the various processes of purification, on the removal of color by means of carbons, etc., on the keeping qualities of the sugar, and on many other characteristics are most important. There is great need, not only of research in this field but of a greater dissemination of even our present small knowledge of the subject.

During the year apparatus for the electrometric determination of the hydrogen-ion concentration of sugar solutions has been set up, and measurements of a series of soft sugars have been carried out. Work is now in progress on the determination of the titration curves for these same sugars over a range extending somewhat above and below a value of $P_H 7$, which is generally assumed to be the point of neutrality. A very successful titration vessel and electrode have been devised for the purpose. The equilibrium rates for this titration are slow and the measurements, therefore, tedious.

Molasses Formation (Proffitt).

One of the most urgent problems confronting the sugar technologist in the line of improved practice is that of reducing to a minimum the quantity of molasses produced. Molasses formation is brought about by the presence of impurities in the sirups from which the sugar is crystallized. In any factory or refinery sirup, the impurities, together with the sugar and water in which they are dissolved, form a chemical "system" whose properties vary according to the kinds of impurities present and to the relative proportions of the various constituents in that particular sirup. Thus, if sufficient water is removed by evaporation under suitable conditions, the sirup will become supersaturated and solid matter will separate out in the form of crystals until equilibrium is attained or the process is otherwise interrupted. At first the separating crystals may form quite rapidly and may consist of nearly pure sugar; later, as the proportion of sugar to impurities becomes less and less, other substances will appear along with the sugar crystals in greater and greater proportions with respect to associated sugar and in continually changing proportions with respect to each other. Finally, the crystallization will proceed so slowly or the crystals will contain so small a proportion of sugar that it does not pay to continue the process. Strange as it may seem, very little is known about the true character of these various systems, and so it happens that the sugar technologist can do very little consistent or even intelligent work toward

reducing sugar losses in the form of molasses until he has been provided with fundamental data on the physical and chemical properties of the systems with which he has to deal in the common sirups of the sugar factory and refinery. It is in work of this kind which the bureau is carrying on under this caption that distinct accomplishments have been made in this field during the year.

Standardization of Commercial Sugars.

The work on the problem of establishing scientific specifications which would rigidly grade and standardize the commercial sugars has been continued with satisfactory results. That the problem is a most difficult one involving both economic factors and scientific research of a high order, has long been recognized. Several hundred samples have now been analyzed and investigated, a number of definite physical properties having been accurately determined in addition to the general chemical and color analysis. The success thus far attained in the research has only been made possible by the fullest cooperation of the entire domestic-sugar industry. Final application of the specifications and definitions will necessarily have to be made in a large degree by a committee representing the manufacturing sugar companies. In the bureau's efforts to differentiate accurately between commercial sugars the broadening of the field of inquiry has been unavoidable until it now includes the chemical precision methods of inquiry, the observed relation between acidity, hydrogen-ion concentration, invert sugar, etc., and a spectrophotometric analysis by the use of a new photometer for technical laboratories and screen tests.

Elimination of Nonsugars (Proffitt).

Of all the various sources of manufacturing losses in the sugar industry none is more important than that of the loss of sugar in the form of molasses. These losses, as elsewhere explained, are due directly to the presence of impurities or nonsugars in the sirups from which the sugar is crystallized, and every pound of such impurities which is finally present causes the loss of $1\frac{1}{2}$ pounds of sugar and the rehandling of sirups equivalent to 8 or 10 pounds of sugar and nonsugar. Hence, the importance of finding conditions for attaining the greatest elimination of impurities from the sirups before crystallization is begun. In the case of the beet-sugar process, which is being investigated first, the most promising field for research would seem to be a study of (1) the factors influencing the relative dialysis and diffusion rates of sugar and some of the known nonsugars of the beet, (2) the reactions and equilibrium of the carbonation process, and (3) the reactions and equilibria involved in the various saccharate processes. During the past year an investigation of this field has been started and preliminary work with some of the saccharate reactions involved has been carried out.

Laboratories for Sugar Technology (Proffitt).

The development of laboratories with the necessary flexible equipment for research work in sugar technology has proceeded slowly. However, in view of existing conditions, satisfactory progress has been made. Several important pieces of equipment and a considerable amount of much-needed piping and power-transmission machinery have been installed. The bureau's efforts have been greatly

aided by the sympathetic interest and cooperation of the makers of sugar-manufacturing equipment.

Calibration of Flasks (Bates, Snyder).

An accurately calibrated 100-cubic centimeter flask is an invaluable adjunct to all sugar laboratories. Great difficulty has always been experienced by both the Government and the industry in securing a sufficient number. Owing to the large amount of apparently unavoidable breakage it has been necessary to limit the cost in every way possible. This has been difficult, owing to the unusually accurate calibration required for glassware of this character. In recent years, due to the element of labor involved in calibrating, costs have risen inordinately, and it has been difficult to maintain an adequate supply of sugar flasks for the various customs laboratories. The only possible solution of these difficulties appears to be the development of some device which will permit of accurate and yet rapid calibration. Such a device, if applicable to a standard 100-cubic centimeter sugar flask, would also be equally available for other volumetric flasks.

During the year the bureau, in carrying out further investigations of this subject, has apparently been able to develop a satisfactory calibrating instrument. It is an improved and perfected form of a device used by one of the Cuban sugar companies. The desired volume of acidulated water is delivered into the unmarked flask, and the position of the meniscus in the neck of the flask is rapidly and accurately located by means of an electrode lowered by a micrometer screw. An electric circuit is thereby completed, and use is made of telephone receivers to determine the instant of contact. A steel pointer is brought into contact with the waxed neck of the flask and revolved around the neck. The mark is then etched in the usual manner. This device permits of the graduation of flasks ranging in capacity from 25 to 1,000 cubic centimeters with equal facility.

The results thus far obtained with the device have been most satisfactory, and its operation does not require a skilled manipulator. It is expected that the drawings and specifications will be made available to American manufacturers during the coming year.

Development of Sugar Balance (Bates, Snyder).

There has long been a need for a rapid and accurate balance especially designed for the weighing of sugar. This need is as important to the Government, especially for the testing of imported sugars by the customs service, as to the industry as a whole. The requirements are peculiar to the service demanded, and as a result the balances used have been of the greatest diversity of design and unsuited for the purpose. The customs service necessarily imposes very hard and continuous usage on sugar balances. During the year the bureau was able to design a balance and thoroughly investigate the various changes which were finally incorporated. A specimen balance was eventually built by an American manufacturer, and an exhaustive test in its final development, extending over several months, has proved its complete practicability and accuracy. Among the more important innovations may be mentioned the utilization of knife edges and planes of agate, which effectually prevent the corrosion of balances in tropical climates; single-armed hangers for the support

of the pan and scoop to permit of the rapid extraction or insertion of sugar without danger of spilling and giving a maximum space for manipulation; the complete elimination of exposed parts to which spilled sugar can adhere, thereby producing one of the most common sources of inaccuracy in weighing; the equipment of both center and end knife edges with arrests, thus preventing damage to the edges during loading and unloading; sugar scoop counterpoised with pan and interchangeable with it to permit the use of the scoop on either side of the balance; and sensibility adjustable to one-half miligram. The balance has already been adopted by one manufacturer, and is now in quantitative production.

3. COLORIMETRY.

I. G. Priest.

Spectrophotometric and Spectroradiometric Methods (Gibson, Mc-Nicholas, Priest).

The fundamental specification of the stimulus of color is the spectral distribution of relative radiant power—that emitted by incandescent sources, or that transmitted or reflected by transparent or opaque materials. Methods of measuring such spectral distribution in the ultra-violet and infra-red as well as in the visible are therefore continually being developed or improved. Speed as well as accuracy are desired. Progress the past year has been as follows:

1. New and improved apparatus has been designed for the proper illumination of materials, the spectral reflection of which is to be measured. This will be used with the König-Martens spectrophotometer. Plans have also been made for the use of such illumination with a spectrophotometer similar to the Keuffel and Esser color analyzer for the direct-reading measurement of spectral reflection and transmission.

2. A revision of the exponential spectrophotometer (described in previous reports) is being made which will make possible the direct-reading measurement of the spectral transmissivity of dyes.

3. The photoelectric cell is used in the violet, blue, and green to supplement the visual and photographic methods. The null method with electrometer has been replaced by an equal deflections method with galvanometer, and by the addition of a Brodhun variable sector spectral transmissions are now read directly. Without loss in accuracy, the speed and ease of operation have thus been greatly increased and all computation eliminated. A paper describing the method (now in press) will appear in the Journal of the Optical Society of America.

4. The use of the Brodhun sector also makes possible a direct-reading thermoelectric method, the thermopile replacing the photoelectric cell. The method has been employed to a considerable extent in the red and near infra-red regions of the spectrum. The combined photoelectric and thermoelectric methods (one apparatus) completely cover the visible spectrum. As brought out in past reports, this overlapping of methods is very desirable.

5. Several minor improvements have been made in the photographic method of measuring spectral transmission. This method, used in the blue, violet, and ultra-violet, is the sector photometer, null method, and is also practically direct reading.

Visibility of Radiant Energy (Gibson).

By this expression is meant the ratio of luminosity to radiant power—the luminous efficiency—at the various wave lengths in the spectrum. The results of the cooperative investigation with the Nela Research Laboratories (described in last year's report) are being published as a bureau scientific paper (now in press). Detailed descriptions of the method and apparatus are given in this paper, as well as a discussion of precision and reliability. Several of the observers had been used in previous investigations, and thus an excellent comparison has been afforded between these several determinations. As a result of this investigation a revision of the I. E. S. mean visibility curve is proposed, which gives better agreement with the extensive experimental data. It is planned to establish permanent apparatus at the bureau for the measurement of this important function.

Spectral Transmissive Properties of Dyes (Frehafer, Gibson).

The dye standardization program of the bureau is in charge of the chemistry division. The color of a dye solution is fundamentally specified when its spectral transmissive constants are known, and therefore such specifications constitute one of the possible methods of testing the purity of a dye. The colorimetry section is thoroughly equipped for such measurements and is cooperating with the chemistry division in this part of the standardization program. While much of this work is preliminary, it is regarded as essential to a full understanding of the problem.

Twenty-one different kinds of dyes (about 150 solutions) have been tested visually with the homogeneous mercury and helium lines, and in some cases the region of maximum absorption studied. In one case 13 samples (most of them commercial) of a single dye were thus compared. No two of them were found alike. The work will be continued the coming year.

Miscellaneous Spectral Transmission Measurements (Gibson, McNicholas).

Among the many such measurements that have been made the past year the following are worthy of special note: (1) Japanese and American signal roundels were compared in anticipation of large orders for such glass being placed by the Chinese Government railroads. The Japanese roundels failed to meet the requirements of the (American) Railway Signal Association. (2) The transmission of nicol prisms has been measured throughout the ultra-violet and visible. Those so far examined have been slightly yellowish and have not transmitted very far into the ultra-violet.

Spectral Reflection of Enamels (Frehafer).

In cooperation with the enameled metal products section of the ceramics division the spectral reflection of nearly white enamels of different compositions was examined. The opacity of these surfaces is not easily judged by the eye when the surfaces are very nearly the same. Hence, a more accurate method was resorted to, namely, their total reflection for sunlight (computed from the spectral reflection), in order to grade them accurately with respect to opacity. The results are embodied in an article "The effect of some substitutes

for tin oxide on the opacity of white enamels for sheet steel," published in the May Journal of the American Ceramic Society.

Cooperative Investigations with the Munsell Color Co., March, 1922, to February, 1923 (Priest).

At the request of the Munsell Color Co. the bureau has cooperated with them on some of the fundamental problems in color standardization. All of the work has been done in the bureau's laboratories with its own facilities. The company has paid the salary of one research associate who has worked at the bureau on these problems. The principal accomplishments to date are:

Development, construction, and installation in the bureau of new and improved apparatus for the analysis of color stimulus in terms of dominant wave length and purity, paying particular attention to careful standardization and refinements of measurement. This apparatus is now being used with satisfactory results.

Preparation for the determination of hue sensibility to wave-length difference.—In this investigation it is planned to determine (for a large number of observers and as a function of wave length, intensity, and purity) the smallest wave-length differences just perceptible as color differences. The rather elaborate apparatus has been assembled and preliminary tests made of it. It is expected that this work will be resumed during the coming year.

Continuation of investigation of the psychologic standard of white light previously begun at the bureau. (B. S. Sci. Paper 417.)—Progress has been made on studies of the conditions of this experiment and reports of progress have been published. Considerable unpublished data are on hand which can not be published until further experimental work has been done. It is expected that the bureau will continue this investigation.

The colorimetry and photometry of daylight and incandescent illuminants by the method of rotatory dispersion.—Further studies, both theoretical and experimental, have been made on the methods of photometry and colorimetry previously proposed by Priest.

In the light of this work, the method is now proposed as a complete and satisfactory solution of the practical problem of the visual photometry and colorimetry of all illuminants (including the important phases of daylight) whose spectral distribution approximates the Planckian formula closely enough to give a color match. This solution is based upon the principle of the additivity of homogeneous luminosities and the assumption of a standard visibility function.

The method falls in the general class of substitution "equality-of-brightness" methods. All brightness matches are made at a color match. This color match is obtained by modifying the color of a constant comparison source by allowing its light to pass through a train of nicol prisms and quartz plates which form, in effect, a blue or yellow filter of continuously adjustable spectral transmission.

Tables and graphs have been prepared by which color temperature and candlepower or brightness may be readily obtained from the instrument readings on the basis of any visibility which it is desired to assume as standard.

A model instrument has been constructed in the Bureau of Standards instrument shop.

The method was described and the instrument exhibited at the meeting of the Optical Society of America, Washington, October, 1922.

Preliminary data on the color of daylight at Washington.—The average color of daylight and information as to the usual diurnal and seasonal departures from this average are, of course, important fundamental data in colorimetry. It has been found that the color of daylight may, in general, be conveniently specified on a scale of "color temperature"; that is, in terms of the hypothetical temperature of a complete radiator which would emit light of the same color. From time to time observations of this kind have been made on various phases of daylight at Washington. Some of the preliminary data already obtained have been published.

4. REFRACTOMETRY AND OPTICAL INSTRUMENTS.

I. C. Gardner.

Testing of Photographic Lenses (Bennett).

The measurement of the aberrations and other optical characteristics of photographic lenses was first begun in the spring of 1921 at the request of the Army Air Service. A report was made to the Air Service on the 14 lenses submitted at that time. Because of the value of these measurements in determining the types of lens most suitable for use in airplane photography it was decided in the spring of 1922 to investigate the characteristics of photographic lenses on a more extensive scale. Accordingly, 27 other lenses of various manufacture were supplied by the Air Service for this investigation. Measurements of the aberrations, aperture ratios, and focal lengths of these lenses were made, as a result of which the bureau has placed at the disposal of the Air Service data on a total of 41 lenses.

The results of these tests are represented graphically, enabling the degree of elimination of the various aberrations to be readily determined.

In order to familiarize the members of the engineering division, Air Service, with the procedure which the bureau has found to be most convenient as well as reliable for the testing of photographic lenses, a detailed report explaining the methods was also furnished them.

As a further result of this work the section is now in possession of a collection of data on the performance of practically all the high-grade photographic lenses on the market upon which a standard of excellence may be based and which serves to indicate the lines which an attempt to improve this type of lens should follow.

Tables for the Design of a Telescopic System (Gardner, Tilton, Arnaud).

Work has been continued upon the completion of tables to be used in the design of telescopic systems. At present the design of the eyepiece is being developed and the computations are completed for the Kellner type of eyepiece constructed from dense flint and barium crown glasses.

Letter Circular on the Design of Telescope Objective (Gardner, Tilton).

Requests are frequently received for information regarding methods of designing astronomical telescope objectives. Accordingly a letter circular has been prepared and mimeographed which gives complete instructions for the design of a telescope objective. The information contained in this circular is not novel, but previously has been available only in books or bound copies of scientific periodicals not conveniently accessible to amateur astronomers.

A 12-inch Telescope Objective (Clacey, Finn).

A 12-inch telescope objective has been designed and is now being completed at the bureau. The barium crown and flint blanks were made in the bureau's glass plant, and the designing, lens grinding, and edging are entirely completed. The polishing of the surfaces and the local retouching which are necessary if the spherical aberration is to be satisfactorily eliminated are at present under way. The focal length of the objective is 12 feet.

Laboratory Telescopes (Case).

The designs have been completed of two new laboratory telescopes which are larger than the No. 1 size built last year. Work on two lots of these to be used as standard equipment is progressing in the shop.

Design of Lens for Camera Obscura (Gardner).

An objective was designed for the Ordnance Department, United States Army, which is to be employed in a large camera obscura used in connection with their proof work at Aberdeen Proving Grounds. The final design specifies two separated components with a diaphragm placed at the optical center of the system. The objective was constructed by the Ordnance Department at Frankford Arsenal in accordance with a design prepared by the bureau, and is now in use.

Auto-Collimating Device for Geneva Spectrometer (Gardner, Eckel).

An attachment has been designed and completed by which the section's Geneva society spectrometer may be converted into an auto-collimating type of instrument. This will enable more precise measurements to be secured with the spectrometer, and it is expected that at the same time it will lessen considerably the time required for a determination of index of refraction. The section has also begun the design of a spectrometer of greater precision which, when completed, will supplant the present instrument for work where the highest accuracy is desired.

Direct Vision Spectroscope Prisms (Gardner).

Two 5-component direct-vision spectroscopy prisms of different sizes have been designed, and the construction of six sizes of each to be used as standard equipment has been authorized.

Apparatus for Measuring Transmission of Optical Glass (Eckel).

A new apparatus for determining the transmission of optical glass has been installed and operates satisfactorily. The errors arising from stray light are much more effectively eliminated than in the

older apparatus. This instrument is used in measuring the transmission of samples from the different melts made at the bureau's optical glass plant.

A Magnifying Stereoscope (Gardner, Case).

In the last annual report reference was made to a request received from the Coast and Geodetic Survey for the design and construction of a magnifying stereoscope to be used in viewing photographs taken from airplanes for the construction of maps. This instrument, which was designed and constructed entirely by the bureau, has been completed and delivered.

Field Telemeter (Gardner, Tilton, Case).

In the last annual report mention was made of a field telemeter, a convenient portable instrument for reconnaissance or approximate surveying which was developed at the Bureau of Standards for the use of the United States Geological Survey. This instrument has been used in the field for a year with satisfactory results. It was returned to the bureau for modification in order to adapt it for use with longer stadia rods, and was then recalibrated. It is being used in the field again this year.

Small Camera Obscura for Aberdeen Proving Ground (Bennett).

A request has been received from the Ordnance Department, U. S. Army, for the design and construction of three small camera obscuras to be used on the small-arms range, Aberdeen Proving Ground. The designs have been completed and work has begun on the construction.

5. RADIOMETRY.

W. W. Coblentz.

Optical Specifications of Glass for Balloon Hangars (Coblentz).

In the annual reports of 1919 and of 1921 mention was made of investigations of colored glass, varnishes, etc., for excluding the ultra-violet rays of sunlight from balloon hangars and other buildings containing materials which are injured by photochemical action.

The original specifications, for which this bureau was not responsible, required that glass for balloon hangars shall exclude 85 per cent of the ultra-violet rays and 55 per cent of the infra-red rays of the sun. This requires the use of sunlight as a source of radiation for making the test, which is inconvenient in view of the fact that the measurements can be made only when the sun is available. To put this testing work on a convenient basis, the spectral transmission of the glasses submitted for the test was determined also for various wave lengths, using the ultra-violet emission spectrum of a quartz mercury arc lamp for the ultra-violet and a gas-filled tungsten lamp for the infra-red, and specifications drawn up for this as sources.

In this manner it was established that in order that a colored glass (or a clear glass covered with asphaltum paint) shall exclude 80 to 85 per cent of the total ultra-violet radiation from the sun, its ultra-violet spectral transmission ("Tr" including reflection) should not exceed the following values: At 0.405μ Tr=30 to 40 per cent; at 0.365μ Tr=12 to 15 per cent; and at 0.313μ Tr=0.5 to 1 per cent.

The transmission of infra-red radiation from the sun and from a gas-filled tungsten lamp under normal operation through these glasses was not markedly different. For the glasses thus far tested the transmission (including reflection losses) varies from 25 to 35 per cent, which is well below the value set in the original specification. Since the exclusion of the ultra-violet rays appears to be of primary importance and that of the infra-red rays of secondary importance, it seems desirable to insist upon the exact adherence to the specifications for elimination of the ultra-violet (solar) rays.

The glasses tested were of the wired type, with one side rough or corrugated. The corrugations or roughnesses were removed and the surface polished. Measurements were made on areas clear from wire, bubbles, and opaque spots. With the corrugations present, the average transmissions of the clear areas would be somewhat lower (the exclusion of the ultra-violet would be higher) than cited above. However, these values establish a criterion for judging the optical qualities of the glass.

Emissivity of Cotton Tent Cloth (Coblentz).

In last year's report attention was called to an investigation of the most efficient roofing material which will keep the inside of a balloon hangar at a minimum temperature when exposed to the sun.

It was shown that the most efficient means for excluding the effects of heating from solar radiation from the interior of a building is by covering the outside of the roof with a highly reflecting substance (white paint, asbestos, etc.) and painting the inside of the roof with aluminum paint, which is a poor radiator of the low-temperature long-wave-length radiation emitted by the roof.

During the past year a similar study was made of white cotton (duck) cloth such as is used for tents. As is well known, when a tent is exposed to the sun the interior becomes uncomfortably warm as a result of sunlight which is diffusely transmitted through the cloth and, in particular, as a result of the heat rays emitted by the cloth. By covering the inside of the cloth with aluminum paint it was found that this heat radiation into the interior of the tent can be greatly reduced.

For example, it was found that the radiation from the rear side of a sample of No. 10 duck was reduced by 86 per cent by painting the inside with aluminum. If the aluminum coating is on the outside, the arrangement is less efficient, the radiation into the interior being reduced by only 78 per cent.

While No. 4 duck would be too heavy for tents, it is interesting to note that by applying a coating of aluminum paint on the interior the heat radiation into the interior is reduced by 78 to 81 per cent.

It is obvious that while such a tent would be more comfortable in the daytime the use of the coating of paint would act in the reverse direction and retain the heat generated within, thus maintaining a higher temperature during the night.

The foregoing data have already found application by makers of tents and by persons dealing with refrigeration problems.

Recently the question was raised by the Weather Bureau concerning the effectiveness of a paper covering for protecting orange trees from frost. Paper, like cloth, has a high emissivity for infra-

red rays. Hence, in order to prevent the rapid cooling of the tree it appears that the paper hood should be covered with a coating of aluminum paint.

Germicidal Action of Ultra-Violet Radiation (Coblentz).

In collaboration with the Bureau of Plant Industry (Doctor Fulton), office of fruit-disease investigation of the Department of Agriculture, an examination was made of the fungicidal effect of ultra-violet light, with special reference to the abiotic effect upon molds which affect oranges. Experiments were made upon affected fruit; also upon culture media containing fungi. The results obtained seemed of sufficient importance to warrant undertaking an investigation which has been under consideration for some years, namely, a quantitative determination of the relation between the energy and the germicidal action of ultra-violet rays of different wave lengths.

This investigation should demonstrate the effectiveness that accrues from the collaboration of two widely differing fields of scientific activity—for example, physics and biology—in a problem of mutual interest.

Application of Radiometry to Astronomical Problems (Coblentz).

One of the functions of the radiometry section of this bureau is to develop instruments and methods of radiometry. In performing this function it was found that thermocouples of special design offered a means of solving certain astronomical problems. In cooperation with two astronomical observatories having large reflecting telescopes opportunities were presented to demonstrate the usefulness of these thermocouples in astronomical investigations. The results obtained open up a new line of investigation on stellar evolution, stellar temperatures, variable stars, planetary radiation, etc.

In this connection it is relevant to recall that eight years ago when the first tests were made astronomers were so skeptical of the sensitivity of the stellar thermocouple that doubt was expressed as to its utility for astronomical investigations and advice was given against attempting to use it for such purposes. In the meantime, as a result of this demonstration, the technique of construction as well as the design of the thermocouple radiometer have been adopted by astronomers, and copies of this instrument have been in use for years in connection with the largest and most valuable reflecting telescope as an additional means of studying celestial objects. During the past year two papers (Sci. Papers Nos. 438 and 460) were published describing the results of tests of newly devised instruments for measuring stellar and planetary radiation.

Photo-electrical Investigations (Coblentz, Eckford).

During the past year considerable time was taken in writing up and publishing the results of photo-electrical investigations, some of which had been in progress for some time.

It has been shown for the first time that crystal structure, chemical constitution, and atomic weight have a specific effect upon photo-electrical sensitivity, just as in previous investigations they were found to have an effect on infra-red absorption spectra. These investigations mark an important advance in the bureau's knowledge of photo-electrical conduction in solids.

Some New Photo-electrical and Thermoelectrical Properties of Molybdenite (Coblentz, Hughes).

During the past year important new data were obtained on the thermal emf which is observed in some samples of molybdenite when exposed to thermal radiation but without an impressed potential. It was found that this thermal emf is positive or negative in spots which are separated by 0.5 to 1 or 2 millimeters, thus acting like a true thermocouple. Furthermore, it was established that the spots exhibiting the maximum positive and negative thermal emf do not necessarily coincide with the spots of maximum photo-electrical sensitivity which are observed when there is an external battery. However, when there is a close coincidence of the loci of maximum thermoelectrical and of photo-electrical sensitivity, the thermoelectrical reaction seems to function like a valve, which amplifies or weakens the photo-electrical reaction, depending upon the direction of the impressed battery current through the crystal. From previous experience the photo-electrical reaction current should be found to be proportional to, but independent of, the direction of the "dark" battery current through the crystal. In the present instance the photo-electric current is amplified or weakened, according as the external battery current flows with or against the thermoelectric current. As a result of this selective action instead of obtaining the same photo-electrical reaction (the same galvanometer deflection after correction for any difference that may exist in the "dark" conductivity) on reversal of the battery current there is an outstanding difference of 1.5 to 2.5 times between the maximum and the minimum photo-electrical effect. This is true of both positive and negative maxima of thermal emfs.

7. PHOTOGRAPHIC TECHNOLOGY.

R. Davis.

Action of Charred Paper on the Photographic Plate (Davis).

The method for deciphering written and printed matter mentioned under the above topic in last year's annual report was published in Scientific Paper No. 454, under the title "Action of Charred Paper on the Photographic Plate and a Method of Deciphering Charred Records."

Design of Apparatus for Investigating the Reciprocity Law (Davis).

The so-called reciprocity law in photography states that the effect of light on a photographic plate (or paper) is proportional to the product of light intensity by exposure time. This photochemical law which permits important simplifications to be made in sensitometric practice is questioned for extreme cases. The subject is of considerable importance because of its bearing on the theory of the latent image and on astronomical photography and sensitometry. Special apparatus to investigate its possible failure has been designed and is now under construction.

Standard Lamps for Sensitometry (Davis).

A group of standard lamps for use in the photographic industry were seasoned, color matched, and their candlepower measured with the cooperation of the colorimetry section of this division and with the photometry section of the electrical division.

Sensitometric Tests (Davis).

About 60 experimental emulsions prepared by the spectroscopic section were tested. Such tests involve, in general, the determination of the "characteristic" curve, the photographic speed, spectrograms, and filter factor.

Camera Design (Davis).

A special camera was designed for the electrolysis section of the electrical division to photograph on a continuous strip, either full size or half size, the entire outside surface of 6-inch lengths of $1\frac{1}{2}$, 2, 3, and 6 inch sizes of cast-iron pipe exhibiting the effects of soil corrosion. In this the camera remains stationary while the pipe is rotated and the film shifted synchronously past a narrow aperture (in the focal plane of the objective) parallel to the axis of the imaged cylinder. The camera is now under construction.

8. INTERFEROMETRY.

C. G. Peters.

Thermal Expansion (Peters, Merritt).

The extreme sensitivity of interference methods makes it possible to measure the dimensional changes of small samples with great precision. The expansion of samples 1 to 10 millimeters in length can be determined with an uncertainty of not more than one-half of 1 per cent with the temperature control apparatus now available, and measurements can be made in the temperature interval—150 to $+1,000^{\circ}\text{C}$.

During the past year such tests have been made on samples of commercial and optical glass, cast steel, Monel metal, brass, fused quartz, platinum, and platinum-palladium alloy.

An extensive investigation of the thermal expansion of ceramic materials, such as terra cotta, tile, glaze porcelain, etc., has also been carried out and the results are being prepared for publication.

Calibration of End Standards (Peters).

The work of comparing the precision gauges of manufacturing concerns with the bureau's end standards has been continued. Several redeterminations of these end standards by direct comparison with the standard light waves has been made during the year for the purpose of testing their permanency. In addition to this work, a number of end standards were calibrated for companies engaged in the manufacture of precision gauges.

Ruling of Line Standards (Peters).

Scales have been ruled using a Michelson type of interferometer and light waves as the working length standard. Twelve such scales, 6 inches in length with 40 rulings to the inch, were ruled for a manufacturer of precision scales. In these the maximum error of any interval was less than 0.00001 of the interval. Several scales 10 centimeters in length divided into millimeter divisions were also ruled. A number of small scales 1 millimeter in length with lines 10 microns (0.01 millimeter) apart were made, the maximum error in any interval being less than 0.03 micron.

Precision Determination of Refractive Indices (Peters).

Several different types of interferometers have been used to determine the indices of refraction and the dispersion of solids, liquids, and gases and also the variation of the refractive index and dispersion with temperature and pressure.

Using an interference method, the absolute index of refraction and its variations with temperature have been measured for several different kinds of glass. These measurements are accurate to about one in the sixth decimal place.

Using an interferometer specially designed for the purpose, the indices of water, water solutions, and transparent oil have been determined. The results so obtained were correct to one in the sixth decimal place. For such precision the temperature must be constant to 0.01°C .

Dimensional Changes of Materials (Merritt).

With the interference apparatus referred to in the report of last year, changes in length of 0.05 micron in samples 5 centimeters long can be detected. Repeated measurements made on 100 samples of gauge steel prove the reliability of this apparatus. Measurements on a large variety of materials are planned for the coming year in order to determine the effect of time and treatment on the stability of the materials.

TESTING, INFORMATION, AND PUBLICATIONS.

Tests Completed During the Year.

Work of routine nature completed during the year, amounting to about 3,800 articles tested, covered: Spectrum tubes (28), photosensitizing dyes (5), spectro-chemical analyses (214), polariscopes (43), polariscope cover glasses (800), samples of raw sugar (1,900) and molasses (40), characteristics of glass (20), quartz control plates (50), spectral transmission of glasses and other material (20), spectral reflection (3), dominant wave length (2), relative radiant power and color temperature of lamps (2), binoculars (10), photographic lenses (33), refractive indices (116), dispersion and transmission of optical glass and other substances (42), refractometers (7) and miscellaneous optical instruments (120), standard sources of radiation (10), photoelectric cells (7), eye-protective glasses (32), thermal expansion (118), planeness of surfaces (12), calibration of end standards (44), dimensional changes (100), and ruling line standards (15).

Information, Cooperation with Societies, etc.

An important part of the division's activities has consisted in furnishing information on scientific and technical subjects relative to its work, by extensive correspondence, reports, or directly to technical men visiting its laboratories.

Members of the division have cooperated in the activities of various scientific and technical societies, including the Optical Society of America, the International Astronomical Union, the sugar section of the American Chemical Society, the Illuminating Engineering Society, and the American Engineering Standards Committee.

PUBLICATIONS.

The following papers relating to the work of the division have appeared during the year among the publications of the Bureau of Standards:

- Practical spectrographic analysis, W. F. Meggers, C. C. Kiess, and F. J. Stimson, B. S. Sci. Paper No. 444, 18, p. 235; July, 1922.
- Regularities in the arc spectrum of molybdenum, C. C. Kiess, B. S. Sci. Paper (in press).
- Wave-length measurements in the arc spectra of gadolinium and dysprosium. C. C. Kiess, B. S. Sci. Paper No. 466, 18, p. 695; 1923.
- Measurement of the color temperature of the more efficient artificial light sources by the method of rotatory dispersion, I. G. Priest, B. S. Sci. Paper No. 443.
- The visibility of radiant energy, K. S. Gibson and E. P. T. Tyndall, B. S. Sci. Paper (in press).
- Spherical aberration of thin lenses (T. Townsend Smith), Sci. Paper No. 461.
- Spectrophoto-electrical sensitivity of argentite, W. W. Coblentz, Sci. Paper No. 446.
- Spectrophoto-electrical sensitivity of bournonite, W. W. Coblentz and J. F. Eckford, Sci. Paper No. 451.
- Spectrophoto-electrical sensitivity of some halide salts of thallium, lead, and silver (W. W. Coblentz and J. F. Eckford), Sci. Paper No. 456.
- Further test of stellar radiometer and some measurements of planetary radiation (W. W. Coblentz), Sci. Paper No. 460.
- Various photo-electrical investigations (W. W. Coblentz), Sci. Paper No. 462.
- The action of charred paper on the photographic plate and a method of deciphering charred records (Raymond Davis), Sci. Paper No. 454.

The following papers were published in outside journals during the year:

- False spectra from diffraction gratings (W. F. Meggers and C. C. Kiess), J. O. S. A., 8, R. S. I., 6, p. 417; July, 1922.
- Series in the arc spectrum of chromium (C. C. Kiess and Harriet Knudsen Kiess), Science, 56, p. 666; 1922.
- Regularities in the arc spectrum of iron (F. M. Walters, jr.), Jour. Wash. Acad. Sci., 13, p. 243; 1922.
- Regularities in the arc spectrum of titanium (C. C. Kiess and Harriet Knudsen Kiess), Jour. Wash. Acad. Sci. (in press).
- The effect of some substitutes for tin oxide on the opacity of white enamels for sheet steel (R. R. Danielson and M. K. Frehafer), Jour. Amer. Ceramic Soc., May, 1923.
- Direct-reading photo-electric measurement of spectral transmission, for publication in the Jour. Opt. Soc. Am. (in press), K. S. Gibson.
- A field telemeter for approximate surveying (I. C. Gardner), Jour. Opt. Soc. Am., 6, p. 489; 1922.
- Some observations on the transformation of thermal radiation into electric current in molybdenite (W. W. Coblentz), Jour. Wash. Acad. Sci., 12, p. 411, November, 1922; Jour. Opt. Soc. Am., 7, p. 63, January, 1923.
- Recent measurements of stellar and planetary radiation (W. W. Coblentz), Opt. Soc. Committee Report, 1922, Jour. Opt. Soc. Am., 6, p. 1016; December, 1922.
- Thermocouple measurements of stellar and planetary radiation (W. W. Coblentz), Opt. Soc. lecture, Popular Astronomy, February, 1923.

The papers listed below were presented before meetings of scientific societies during the year:

- Interference measurements of secondary standards in the iron arc spectrum (W. F. Meggers), American Astronomical Society, September, 1922.
- Spectral regularities in the arc spectra of chromium and molybdenum (C. C. Kiess), American Astronomical Society, December, 1922, and Philosophical Society of Washington, January, 1923.
- Practical spectrographic analysis (W. F. Meggers), American Institute of Mining and Metallurgical Engineers, February, 1923.

- The visibility of radiant energy (K. S. Gibson and E. P. T. Tyndall), Optical Society of America, at Washington, October 25-28, 1922.
- Progress on the determination of normal gray light (I. G. Priest), Optical Society of America, at Washington, October 25-28, 1922.
- The effect of various conditions upon the determination of the normal stimulus of gray (I. G. Priest and C. L. Cottrell), Optical Society of America, at Washington, October 25-28, 1922.
- New tables and graphs for facilitating the computations of spectral energy distribution by Planck's formula (M. K. Frehafer), Optical Society of America, at Washington, October 25-28, 1922.
- The colorimetry and photometry of daylight and incandescent illuminants by the method of rotatory dispersion (I. G. Priest), Optical Society of America, at Washington, October 25-28, 1922.
- Preliminary data on the color of daylight at Washington (I. G. Priest), Optical Society of America, at Washington, October 25-28, 1922.
- The visibility of radiant energy (K. S. Gibson and E. P. T. Tyndall), Philosophical Society of Washington, November 18, 1922.
- The invertase value of the Clerget constant (R. F. Jackson, sugar division), American Chemical Society, Pittsburgh, Pa., September 4-8, 1922.
- The contraction in volume of sucrose solutions upon inversion (R. F. Jackson, sugar division), American Chemical Society, Pittsburgh, Pa., September 4-8, 1922.
- A possible system of color classification of technical sugar products (H. H. Peters and E. P. Phelps, sugar division), American Chemical Society, New Haven, Conn., April 2-7, 1923.
- The absorption spectrum of panfeeds, magmas, run-offs, and granulated sugars from magmas (H. H. Peters and E. P. Phelps, sugar division), American Chemical Society, New Haven, Conn., April 2-7, 1923.
- A preliminary note on the color problem of soft sugars (H. H. Peters and E. P. Phelps, sugar division), American Chemical Society, New Haven, Conn., April 2-7, 1923.
- A study of basic lead clarification of beet and cane molasses (R. F. Jackson and R. S. Nowak, sugar division), American Chemical Society, New Haven, Conn., April 2-7, 1923.
- The aberrations of photographic lenses (A. H. Bennett), Washington Philosophical Society, December 16, 1922.
- Thermocouple measurements of stellar and planetary radiation (W. W. Coblentz), Optical Society of America, October 26, 1922.
- Further measurements of stellar temperatures and planetary radiation (W. W. Coblentz), Philosophical Society of Washington, October 7, 1922.
- Some new photoelectrical and thermoelectrical properties of molybdenite (W. W. Coblentz), American Physical Society, Washington meeting, April 21, 1923.

CHEMISTRY.

W. F. Hillebrand.

FUNCTIONS.

The work of this division includes the investigation of the chemical composition and purity of materials, studies of chemical properties and constants, researches in connection with methods of analysis, the preparation of specifications for technical materials for other departments of the Government and for industrial and scientific laboratories. The chemistry division has general supervision of all chemical work at the bureau. In practically all questions of standardization or research, the purity of the materials involved is an important factor. Much of the work of this nature supervised by the chemistry division is described under the appropriate headings elsewhere in this report.

SECTIONS.

1. Paint, varnish, and bituminous materials.
2. Detergents, cements, and corrosion.
3. Miscellaneous organic materials.
4. Inorganic analysis and standard samples.
5. Platinum metals and reagents.
6. Electrochemistry.
7. Gas chemistry.

GENERAL STATISTICS.

Staff	67
Expenditures (1922-23)	\$178,000
Tests completed	8,506
Standard analyzed samples	5,024
Researches completed	35
Bureau publications	34
Outside publications	10

WORK CHART.

I. PAINT, VARNISH, AND BITUMINOUS MATERIALS.

SCOPE.

Pigments.	Paint.
Drying oils.	Varnish.
Volatile solvents.	Bituminous roofing.
Resins.	Waterproofing.
Bitumens.	Related materials.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Paints, pigments, etc.....	1,131	711
Varnish, drying oils, etc.....	445	533
Bituminous materials.....	488	545

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Preparation of 17 specifications for paint and varnish.	Federal Specifications Board.	100	C82, 84, 86-89, 91, 93-94, 97-98, 102-105, 111, 117.
34 specifications in preparation.	do.	50	
Physical properties of paint:			
Some physical properties of paint.....		100	Outside. ¹
Color of paints.....		5	
Moisture-proofing wood:			
Effect of preservative process on properties of wood.		100	LC53.
Efficiency and durability of various coatings on wood.		5	
Miscellaneous:			
Shellac.....		100	T232.
Acid-proof coatings for concrete surfaces.....		Continuing.	LC42.
Shingle stains.....		100	LC64.
Bituminous paints, varnishes, cements, and similar materials.		100	Outside. ²

¹ Proc. A. S. T. M., 22, pt. 2, p. 464; 1922.

² Chapter 24 "Physical and Chemical Examination of Paints, Varnishes, and Colors," by H. A. Gardner; 1922.

2. DETERGENTS, CEMENTS, AND CORROSION.

SCOPE.

Detergents.	Fire-extinguishing compound.
Polishes.	Cement.
Waxes.	Gypsum.
Nondrying oils.	Lime.
Coated metals.	Clay.
Industrial waters.	Sand.
Boiler compound.	Miscellaneous.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Detergents, polishes, etc.....	614	531
Cements, lime, etc.....	814	1,464
Miscellaneous.....	621	161

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Preparation of 10 specifications for soap and soap products.	Federal Specifications Board.	100	C123-132.
Fire-extinguishing liquid specification.....	do.....	100	C134.
Corrosion:			
Total immersion of iron and steel.....		50	
Inhibiting action of chromates in chloride solutions for automobile radiators.		90	
Coated metals:			
Lead-coated steel.....		100	
Nickel-plated plumbing fixtures.....		75	
Brass and bronze-plated hardware.....		75	
Cadmium-coated steel.....		50	
Determination of magnesia and phosphoric acid.....		50	

3. MISCELLANEOUS ORGANIC MATERIALS.

SCOPE.

Rubber.	Inks, typewriter ribbons, carbon paper.
Airplane dopes.	Adhesives.
Balloon fabrics.	Textiles.
Dyes.	Lubricants.

TESTS.

Materials tested	Number completed.	
	1921-22	1922-23
Dope.....		118
Inks, adhesives, etc.....	1,068	962
Rubber.....	667	699
Textiles.....	571	404
Lubricants.....	608	640

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Determination of total sulphur in rubber.....		100	Outside. ¹
Solution method for fillers in rubber.....		75	
Determination of coefficient of vulcanization.....		25	
Maturred, sprayed, and coagulated rubber.....		80	
Special fillers in rubber goods.....		75	
Viscosity and milling of crude rubbers.....		100	Do.. ²
Specifications for rubber goods.....	Federal Specifications Board.	100	
Specifications for packings and gaskets.....	do.	100	Do.. ³
Unclassified rubber specifications:			
Rubber bands.....		100	Do.. ⁴
Druggists' sundries.....	Federal Specifications Board.	20	
Oil suction and discharge hose.....	do.	100	
General specification for rubber goods (methods of testing and analysis).....	do.	100	
Unvulcanized cushion stock.....	do.	100	
Specification for rubber friction tape.....	do.	90	
Specification for rubber insulating tape.....	do.	90	
Submarine cable insulation.....	Army.	25	
Improved balloon fabric.....	Army and Navy	40	
Chemistry of cellulose.....		5	
Preparation of typical dyes.....		80	
Analysis of typical dyes.....		60	
Methods of chemical analysis of dyes.....		20	
Analysis of commercial dyes.....		1	
Chemical identification and determination of cordage fibers.....		25	
Effects of finishing agents upon dyed fabrics.....		20	
Sulphur compounds and oxidation of petroleum oils.....		100	

¹ Rubber Age and Tire News, 9, Nos. 4, 7, 8, 1921.² Fed. Spec. Bd. Specifications 38-51 incl.³ Fed. Spec. Bd. Specifications 1-22 incl.⁴ Jour. Ind. & Eng. Chem. 14, No. 8, p. 728, August, 1922.

4. INORGANIC ANALYSIS AND STANDARD SAMPLES.

SCOPE.

Ores.	Brasses, bronzes, and bearing metals.
Cast irons.	Melting-point standards.
Plain carbon steels.	Sieve standards.
Alloy steels.	Pure chemicals.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Ferrous.....	596	612
Nonferrous.....	649	696

STANDARD SAMPLES.

Character of sample.	Number issued.	
	1921-22	1922-23
Ferrous.....	2,019	3,406
Nonferrous.....	382	444
Miscellaneous.....	1,131	1,174

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Determination of aluminum as phosphate.....		100	Outside. ¹
Notes on determination of phosphorus.....		100	Do. ²
Separation of iron and aluminum from manganese and certain other elements.....		100	Do. ³
Analysis of chrome-vanadium steel.....		100	Do.
Interference of cobalt and certain other elements in the bismuthate method for manganese.....		100	Do.
Determination of aluminum, tin, and bismuth in spelter and manganese ores.....		100	Do.
Analysis of chrome ore.....	Federal Specifications Board.	100	Do.
Analysis of phosphate rock.....		80	
Reduction of titanium in the Jones reductor.....		60	
Determination of aluminum in ferro-alloys.....		60	

¹ Jour. Ind. and Eng. Chem., 14, p. 1136; 1922.² Jour. Ind. and Eng. Chem., 15, pp. 44-47, 171-173; 1923.³ Jour. Am. Chem. Soc., 45: p. 676; 1923.

5. PLATINUM METALS AND REAGENTS.

SCOPE.

Platinum metals: (a) Methods of separation, (b) methods for purification, (c) methods of analysis.

Routine preparation of pure materials.

Routine analysis of platinum-bearing materials.

Reagents: (a) Methods for testing, (b) routine testing.

Preparation of pure substances: (a) Mercury, (b) organic standard samples.

Supervision of chemical storeroom.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Platinum metals and gold.....	9	2
Reagents.....	22	85

PREPARATION OF PURE SUBSTANCES.

Nature of material.	Number prepared.	
	1921-22	1922-23
Platinum metals and alloys.....		13
Benzoic acid.....pounds.....	200	
Mercury.....do.....		600

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Determination of iridium in platinum alloys.....		10	
Analysis of crude platinum.....		75	
Preparation of pure rhodium.....		75	
Analytical separation of rhodium from platinum.....		50	
Preparation of platinum, platinum-rhodium thermo-couples.....		100	Outside. ¹
Platinum alloys for laboratory ware.....		5	

¹ Trans. Am. Electrochemical Society, 1923.

6. ELECTROCHEMISTRY.

SCOPE.

Electrodeposition of metals: (a) Structure, composition, and use of anodes, (b) analysis, properties, and behavior of solutions, (c) structure and properties of deposits, (d) protective value of plated coatings, (e) industrial and Federal applications.

Electrochemical measurements: (a) Conductivity of solutions, (b) hydrogen ion concentration, (c) electrode potentials.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Copper electrotyping solutions.....	50	20
Nickel electrotyping solutions.....	100	10
Nickel salts.....	10	8

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Metal distribution in electrodeposition.....		100	Outside. ¹
Structure of electrodeposits, general.....		50	
Effect of base metal on structure of copper.....		100	Outside. ¹
Nickel deposition:			
Acidity.....		100	LC82.
Effects of impurities—			
1. Copper and zinc.....		100	LC83. Outside. ²
2. Iron.....		100	Do. ³
Behavior of nickel anodes.....		50	
Conductivity of nickel baths.....		90	
Throwing power in nickel baths.....		10	
Deposition of nickel on zinc.....		10	
Preparation of pure nickel.....		10	
Platinum deposition.....		50	
Electrolytic alteration of copper map plates.....		80	

¹ Trans. Am. Electrochemical Soc., 43; 1923.² Trans. Am. Electrochemical Soc., 42, p. 79; 1922.³ Trans. Am. Electrochemical Soc., 32; 1923.

7. GAS CHEMISTRY.

SCOPE.

Material dealt with: (a) Fuel gases, (b) industrial gases, (c) pure gases.

Properties of gases.

Gas reactions: (a) Physical chemistry (equilibria, reaction velocity, etc.), (b) industrial reactions (engineering problems, etc.).

Methods of producing gases: (a) Laboratory production of gases for experimentation, (b) Commercial production.

Gas analysis: (a) Laboratory and reference methods, (b) automatic methods. Process control by analysis.

Utilization of gases.

Balloon fabrics.

TESTS.

Materials tested.	Number completed.	
	1921-22	1922-23
Balloon fabrics.....	223	240
Calcium carbide.....		15
Gas analysis.....		20

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Development of instruments for:			
Determining balloon leaks.....	Army and Navy	100	Outside. ¹
Purity of gas in balloons.....	do.	100	
Airship slide rule.....	do.	100	
Detecting traces of water vapor.....	Department of Agriculture.	90	
Improved gas measuring apparatus (analytical).....		80	
Sample-collecting vacuum pump.....		80	
Determining water vapor (wide range).....		10	
Fractionating gases.....		10	
Combining, recording, and control of various gas measurements.....	Army and Navy	10	
Detecting hydrogen in submarines.....	Navy.....	50	
Processes for manufacturing hydrogen:			
General study of methods.....	Army and Navy	80	Outside. ²
Oil-cracking process.....	do.	100	
Improved steam-iron process.....	do.	95	
Gas absorption.....		40	
Gas analysis by thermal conductivity:			
General study.....	Army and Navy	90	
Physical conditions affecting.....		100	
Chlorine.....		50	
Applications.....		50	
Determination of gasoline in natural gas.....		10	
Mixing gases in constant proportions.....		50	

¹ Annual report of the N. A. C. A.: 1923.

² Chem. and Met. Eng. vol. 23, Nos. 17, 21, and 24, April 30, May 23, and June 18, 1923.

LIBRARY RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Normal densities of gases.....		100	
Critical constants of gases.....		100	
Pressure volume relations.....		40	
Helium.....		100	CS1.

INSTRUMENTS CONSTRUCTED OR CALIBRATED FOR OTHERS.

Type of instrument.	Con- structed.	Calibrated.
Balloon leak detectors.....	2	2
Hydrogen purity indicators.....	2	2
Helium purity indicators.....	4	4
Automatic apparatus for determining ammonia.....	1	.....
Automatic apparatus for analyzing mixtures of nitrogen and hydrogen.....	1	.....
Helium purity recorders.....	3	3
Water vapor detector.....	1	.....
Carbon dioxide recorder.....	1	1
Sulphur dioxide recorder.....	1	1
Gas interferometer.....	.....	1
Set of color standards for determining hydrogen sulphide.....	1	1

Detailed Report of the Year's Work.

GENERAL.

As in past years, a great part of the energy of the division has been expended in the testing of materials submitted by various branches of the Government service. Little of this large amount of testing work can with any propriety be called "routine work," if this term is used in the same sense as it would be used in factory-control work; for not only are numerous difficult tests made on the samples examined, but, from the results of such tests, conclusions are drawn as to the quality and suitability of the materials in question. Hence, a large proportion of the samples examined represent actual research work, and in many cases these apparently minor researches on samples tested require more work than that represented in many published original research papers. Methods of test are continually being devised or revised, and much of this work is made necessary by peculiarities of samples sent in from other branches of the service.

Nearly all sections of the chemistry division cooperated extensively, as in the past, with committees of technical societies and with other agencies. The division is represented on many committees that are engaged in scientific work, and in a number of instances the chairmanships are held by its members. Major organizations with which such cooperation was had are: American Society for Testing Materials, American Chemical Society, American Engineering Standards Committee, Federal Specifications Board, American Concrete Institute, American Electroplaters' Society, Paint and Varnish Manufacturers' Association, Interdepartmental Conference on Chemical Lime, Natural Gas Association, American Foundrymen's Association.

Considerable travel was undertaken for purposes of inspection, field tests, and similar work in connection with studies of corrosion and plant operation, attendance at meetings of committees, etc.

1. PAINT, VARNISH, AND BITUMINOUS MATERIALS.

P. H. Walker.

This section handles the analysis and testing of a great variety of paint and varnish materials and of bituminous materials for waterproofing and roofing purposes. It prepares specifications for such

materials and collects information relative to the service that may be expected from them.

Cooperation with Outside Agencies.

The section of paints, varnishes, and bituminous materials continued to cooperate with the committee on protective coatings of the American Society for Testing Materials in most of its activities. Notable contributions in the report of the committee for 1923 will be: (a) "Standard methods for routine analysis of yellow and orange pigments containing chromium compounds, blue pigments, and chrome green," F. W. Smither, chief of the section on detergents, etc., assisted by P. H. Walker and E. F. Hickson; (b) "Tentative methods for testing shellac," L. L. Steele; (c) reports of the subcommittees on varnish (L. L. Steele), linseed oil (L. L. Steele), physical properties of paint materials (J. G. Thompson), and waterproofing material (E. H. Berger).

The section also assisted a committee of the American Concrete Institute in preparing specifications for waterproofing materials and in studying waterproofing problems (E. H. Berger).

For the Paint and Varnish Manufacturers' Association considerable work was carried out on problems relating to drying oils, color measurements, etc.

For the Federal Specifications Board a very large amount of work was done in preparing 17 completed and 34 still uncompleted United States Government standard specifications (E. F. Hickson, E. H. Berger, L. L. Steele).

Paint and Paint Materials.

In addition to work mentioned in preceding paragraphs, several specifications for limited use were prepared (E. F. Hickson), and the development and improvement of methods of testing were continued. Consultation with officials of the Shipping Board, War Department, and others on particular painting problems has been an important feature of the year's work. Several experimental antifouling paints were prepared in assisting an investigation of a very complex problem that is being conducted by the Navy Department.

A paper on the physical properties of paint marks the beginning of very important work (J. G. Thompson).

Encouraging progress has been made in measuring the color of paints (J. G. Thompson).

Many experiments were made with various coatings in order to study the best methods of preventing moisture changes with subsequent change in volume of wood (C. H. Jumper), but this, like many other paint problems, is so complicated as to require much time and labor expenditure before definite results can be reported.

Varnish and Varnish Materials.

Improved methods of testing shellac have been published and the nature of shellac wax is being investigated.

Data on the hexabromide value of raw linseed oil are being accumulated (Steele), using the method previously devised in this laboratory. Further study on methods of determining "foots" in linseed oil is in progress, because the method devised here, while admittedly better than any other known method, is subject to large percentage errors and therefore objected to by producers of this material.

Bituminous Materials.

The two major divisions of the bureau's study of bituminous materials relate to roofing and waterproofing, to which some reference has already been made. Materials of a nonbituminous nature but which have uses similar to bituminous materials are also included. A great deal of investigational work was done in preparing the numerous United States Government specifications for this type of material and also on nontextile floor coverings and mastic decking (Berger). Information on durability and better methods of construction is constantly being collected. The large amount of consultation work carried on is evident from the following examples: (a) The construction of the bituminous bottom of the Lincoln Memorial Pool, which was practically under the bureau's supervision; (b) specifications for and methods of applying waterproof expansion joints for use on the roof of Lincoln Memorial, the Key Bridge, and the new conduit of the Washington Aqueduct.

The section cooperated with the cement section in an investigation on light-colored damp-proofing compounds for stone and concrete and on the effect of alkali on concrete and with the electrolysis section on soil corrosion.

A member of this section prepared the chapter on bituminous paints, varnishes, cements, and similar materials in a book by H. A. Gardner, entitled "Physical Examination of Paints, Varnishes, and Colors," and other members of the section gave assistance to the author in other ways.

2. DETERGENTS, CEMENTS, CORROSION, ETC.

F. W. Smither.

The field covered by this section includes the chemical analysis and testing of detergents, cement, lime, gypsum, coated metals (such as tin plate and galvanized metals), waters, etc.

Soap Specifications (Walker, Bower).

Tentative specifications were prepared for powdered soap and for saddle soap at the request of the War Department. The specifications reported last year have been issued as circulars of this bureau. Experimental work was done on the solubility of sodium chloride in alcohol in connection with the methods of test prescribed in the various specifications.

Cements, etc. (Whitson).

This section cooperated with the Interdepartmental Conference on Chemical Lime in drawing up specifications for lime for various uses. Further work on the modified Schaife method for the determination of available lime in quick and hydrated limes confirmed the satisfactoriness of this procedure. This method has been published as a tentative standard by the American Society for Testing Materials.

Considerable work of a miscellaneous nature was done in cooperation with the structural materials and other divisions, consisting largely in furnishing special data for their investigations. This work included the analyses of samples of alkali water and soil, waterproofing and composition flooring compounds, gypsum, ganister rock,

fire clay, disintegrated concrete, and comparative analyses of Norwegian and other foreign Portland cements. Studies of certain analytical procedures were also carried out. The testing of samples of the Portland cement used in the construction of the Wilson Dam at Florence, Ala., increased greatly.

Corrosion, Waters, etc. (Sager).

"Total immersion" tests.—Cooperative work on the "total immersion" tests of the committee on the corrosion of iron and steel of the American Society for Testing Materials, conducted in part at this bureau and begun nearly three years ago, is still in progress. Practically all of the 22-gauge iron and steel sheets under test at this bureau have shown failures during the past year. Study of the failures indicates that copper added to the steel does not appear to be a factor in the life of the samples that are totally and continually submerged in running water. The 16-gauge sheets have to date shown no failures. Reports of these tests will be found in the proceedings of the above-mentioned society.

Metallic coatings (Sager).—Owing to press of other work no further progress was made on the standardization of the salt-spray test. Inspection of zinc and cadmium coated materials exposed on the New England coast by the General Electric Co. indicated that in the salt-spray test as at present conducted the corrosive conditions are highly accelerated. Tests made for the Government departments included an investigation of lead-coated iron and steel, tinned and nickeled paper clips, aluminum coated with different types of varnish, duralumin rivets, etc. An investigation of the thickness of coating on nickel-plated plumbing fixtures and on brass and bronze plated hardware was made for the Federal Specifications Board. An investigation of the effect of sodium chromate added to a solution of calcium chloride upon the corrosive properties of the latter when used as an antifreeze material for automobile radiators is nearing completion. The section has given advice on galvanized materials to certain technical committees of the Federal Specifications Board and other branches of the Government.

Water (Sager).—Mineral analyses of waters were made for the Government departments to determine the advisability of purification for industrial use and the means to be adopted, and after the installation of purification equipment analyses of the treated waters were conducted to determine whether specification requirements had been met. Periodic examinations of the treated waters are also made. A member of the bureau's staff is serving as a member of an advisory committee on drinking water standards for common carriers. The bureau, however, does not test waters as to potability.

Miscellaneous work.—A large number of samples was tested for the Steamboat Inspection Service to determine their fire hazard. Several materials were examined for the Federal Trade Commission, including naphtha soaps and ritual candles. Four samples of gasoline were tested for the State of Washington. Cooperative tests were made for the American Hotel Association and advice given in connection with its program for the standardization of detergents and other hotel supplies. Advice was given the National Committee on Prisons and Prison Labor regarding laundry supplies. Various materials were examined for the Government departments:

for example, graphite, boiler scale, boiler compounds, foundry facings, boiler lagging, fire extinguishing compounds, antifreezing solutions for automobile radiators, nondrying oils, so-called carbon removers, and rust preventives, technical chemicals, etc. Many soaps, washing sodas, cleaners, polishes, etc., were examined to guide the various Government departments in making awards to contractors.

3. MISCELLANEOUS ORGANIC MATERIALS.

C. E. Waters.

This section is concerned with chemical analysis and investigations of oils, rubber, paper, textiles, ink, glue, airplane dopes, etc., with special reference to meeting particular requirements.

Airplane Dopes (Smith, Jacobsohn).

The testing of airplane dopes was carried on throughout the year. Although a successful all-metal plane has been developed, there is no immediate prospect of its superseding the plane having wings covered with doped fabric.

Balloon Fabrics (Jacobsohn).

Only a negligible number of samples of rubberized balloon fabrics was received during the year. The investigation for the purpose of developing a balloon-fabric coating having the best qualities of rubber and of goldbeaters' skin progressed very slowly until of late, when some promising results were obtained. The investigation is for the Army and Navy.

Rubber Chemistry.

Notwithstanding numerous changes in personnel, there was only a slight diminution in the number of rubber samples tested. In addition, satisfactory progress was made in the preparation of specifications for rubber goods and various kinds of packings.

In the rubber work there is close cooperation with the structural, engineering, and miscellaneous materials division, which does the physical testing. The physical and chemical testing are under the control of one man. Both sections work together also in the preparation of specifications, and both have a share in cooperative work with scientific societies. The study of new methods of chemical analysis is greatly aided by having samples of known composition prepared by the physical laboratory.

Dye Chemistry (Appel).

A year ago the bureau's dye chemist resigned after only four months' service. In September another chemist was engaged, who has made very satisfactory progress. Numerous dyes of known purity have been prepared as spectrophotometric standards. Methods of chemical analysis have been studied and the results correlated with those of spectrophotometric measurements. There will be further correlation by means of dyeing tests on yarns. Two trips were made to New York to attend conferences about dye standardization with representatives of the Treasury Department and the Tariff Commission.

A few samples of commercial dyes were analyzed. Special attention was paid to the comparative study of several samples of crystal

violet—all the brands that could be obtained. This dye is used for the determination of colloidal matter in molding sand. It had been claimed that only one foreign brand of the dye was satisfactory for the purpose, but the bureau's tests showed that equally good crystal violet is made in this country.

Textile Chemistry (Eichlin).

Most of the chemical work on textiles consists in making chemical tests of materials that are under investigation by the textile section of the structural engineering and miscellaneous materials divisions. In addition to the various routine tests, a study of the effects of different finishing agents upon dyed fabrics was begun. An investigation of the color reactions of the various cordage fibers was also started.

Inks, Ribbons, Carbon Paper (Welch).

Each year many samples of these materials are tested. The peak of the load comes in the spring, when the Post Office Department and the General Supply Committee make contracts for these supplies.

Adhesives (Welch).

Many samples of mucilage and library paste and a moderate number of glue were tested. With these may be grouped a few glycerol compositions, such as hektograph pads.

Finger-printing Device (Welch).

A year ago mention was made of a method of finger printing that was developed for the Postal Savings Division of the Post Office Department. Since then a new device has been worked out and adopted. The fingers are lightly oiled by pressing them upon a glass surface coated with a thin film composed of lead oleate, ferric chloride, and oleic acid. The fingers are pressed upon the document and the print developed by brushing it over with a dilute solution of sodium sulphide. For convenience the sulphide is supplied in the form of tablets which are dissolved as needed.

Lubricants.

During the year many lubricating oils and greases were analyzed, as well as carbon deposits and a sludge from engines (N. Berryman, in cooperation with the structural, engineering, and miscellaneous materials and the heat and power divisions).

As pointed out a year ago, laboratory tests can at best only indicate whether or not a lubricant is likely to be satisfactory in service. One of the causes of the deterioration of oil is oxidation, and further progress was made in the study of the behavior of oils under oxidizing conditions. A paper giving evidence that there is a relation between the sulphur content of an oil and the rate at which it oxidizes was published. A similar study of four transformer oils was made in cooperation with a subcommittee of committee D-9, American Society for Testing Materials. Part of this study was a comparison of the results obtained by Gill's gumming test with those obtained by heating the oils to a relatively high temperature in the air. Further work along this line is contemplated.

4. METAL AND ORE ANALYSIS AND STANDARD SAMPLES.

G. E. F. Lundell.

The work of this section can be divided into three main branches: (1) The development of refined and of routine methods of inorganic analysis; (2) the preparation, standardization and distribution of standard samples of iron, steel, alloy steels, ferros, brasses, bronzes, bearing metals, melting point metals, ores, cements, and pure chemicals; and (3) the chemical analysis of the metallurgical materials used in the bureau's research projects or submitted by other Government departments.

Standard Analyzed Samples (Hoffman, Bright, Scherrer).

The number of standard samples issued during the fiscal year 1922-23 was 5,024, as against 3,532 in the year 1921-22. The distribution was as follows:

Irons and steels.....	3,406
Brass, bronze, and bearing metals.....	192
Metals for melting points.....	252
Ores.....	149
Cements.....	156
Sodium oxalate.....	286
Benzoic acid.....	405
Naphthalene.....	70
Sucrose.....	73
Dextrose.....	35
Total.....	5,024

The sale of standard samples has shown a marked increase during the past year in spite of the curtailment of the number of samples issued to colleges and universities. The fee value of the samples, \$9,451, compares favorably with the appropriation of \$10,000 which was available for the prosecution of the work, and shows that it is practically self-supporting.

The curtailment of samples issued to colleges and universities has reference to samples intended for ordinary student use and not to those needed for standardization or research. To meet the need for student samples the bureau has adopted the policy of using the chips which are not of the standard 20-40 mesh size but which are of uniform composition and well suited for student use. In this way large samples of BOH 0.8 carbon, AOH 0.2 and 0.4 carbon, nickel, and chrome-vanadium steels and sheet brass were prepared and distributed free of charge among 71 schools.

One new standard sample was added to the list during the year (No. 55, ingot iron) and four exhausted standard samples were renewed, as follows: Sheet brass, No. 37b; B O H 0.2 C steel, No. 11c; A O H 0.6 C, No. 21b; and cement, No. 47c. In addition, material has been secured for the following eight new standard samples: Phosphate rock, manganese bronze, phosphor bronze, refined silicon, 75 per cent ferrosilicon, 50 per cent ferrosilicon, high-carbon ferrovanadium, and low-carbon ferrovanadium. Unless unforeseen difficulties in analysis arise these will all be available as standard samples by January 1, 1924.

Cooperation in the Analysis of British Chemical Standards (Hoffman).

In addition to carrying on the analytical work dealing with the bureau's standard samples, considerable analytical work was done on the British chemical standards. In this work the bureau cooperated with American, English, Scotch, French, and Italian analysts in the analysis of the British standard basic slag "A," and carbon steels "P" and "C."

Cooperation in the Development of Standard Analytical Methods (Knowles).

During the year the section cooperated with the subcommittee on analysis of the Committee for the International Standardization of Zinc. Methods for the determination of aluminum, bismuth, and tin in spelter and of manganese in zinc ores were developed at the bureau and adopted by the committee for recommendation as standard methods.

At the request of the American Foundrymen's Association methods for the chemical analysis of molding sand were drawn up by the section and these were adopted by the association as tentative standard methods.

The section also cooperated with the American Society for Testing Materials in the development and the revision of methods of analysis for various nonferrous materials and is now starting work on methods for the analysis of ferros.

In connection with the work of the Federal Specifications Board the section has recommended methods of analysis for materials listed in the specifications. These were mainly selected methods, but certain methods were revised and others were developed.

Umpire Analysis and Standardization of Various Metallurgical Material.

The work in this field was considerably increased during the past year. Umpire analyses were carried out where analysts could not agree, and the bureau was asked to settle the dispute. The policy of the bureau of aiding firms in the standardization of material of which no standards are available was continued, and considerable analytical work was done on the prepared samples which were submitted.

Analysis of Ferrous and Nonferrous Materials (Bright, Scherrer).

This work includes the chemical analysis of such metallurgical products as iron, steel, alloy steels, ferrous, brass, bronze, bearing metals, type metal, boiler plugs, solder, pure metal and coated metals, such as tin plate, galvanized metal, and silverware. These analyses were made for a number of branches of the Government, among which may be mentioned the War, Navy, Treasury, and Post Office Departments, Shipping Board, Panama Canal, General Supply Committee, Government Printing Office, Bureau of Engraving and Printing, and such branches of the Department of Commerce as the Bureau of Lighthouses and the Steamboat Inspection Service. An important function of the section is the analysis of practically all metallurgical material connected with the research projects of the bureau. In addition, several special chemical compounds were prepared for other divisions of the bureau.

5. PLATINUM METALS, REAGENTS, AND APPARATUS.

E. Wichers.

In this work may be mentioned the study of methods of testing reagents and apparatus to be used in chemical analysis, including study of chemical glassware, porcelain, platinum, and platinum substitutes.

Platinum Metals.

The research upon the chemical and physical properties of the platinum metals has been continued. The major portion of the year's work was devoted to the study of methods of analysis of crude platinum and platinum alloys.

Determination of iridium (Gilchrist).—Probably the most important determination in platinum alloys is that of iridium, since iridium alloys are extensively used in a number of industries. An exhaustive critical study of the Deville-Stas method for this determination, commenced during the preceding year, was completed. A large number of analyses were made on specially prepared alloys in order to determine the accuracy of the method, the effect of the presence of other metals in the alloys, and the effect of variation over a wide range in the details of the procedure. Of the metals usually present in complex platinum alloys, iron and ruthenium were the only ones found to cause errors in the iridium value, both being weighed as iridium. In commercial practice ruthenium is frequently regarded as equivalent to iridium and determined as such. A method of correcting the iridium value for iron was developed. A paper setting forth the results of this work, together with a recommended procedure, was prepared for publication.

Analysis of platinum ore (Swanger).—Work on this project, begun last year, is well advanced. The analysis of this material involves the separation of the six platinum metals besides copper, silver, gold, and iron, and the determination of those elements of commercial value, usually platinum, iridium, rhodium, palladium, and gold. A scheme has been outlined which has as its principal object the attainment of greater accuracy in these determinations than is possible with methods now in use without unduly adding to the time required for a commercial analysis. Details of the procedure have been subjected to extensive experiments, and complete analyses have been made of a number of mixtures containing the elements mentioned in known proportions. Some additional work is required before the method will be ready for publication.

Rhodium-platinum separation.—A study of the quantitative separation of rhodium from platinum was begun, there being at present no adequate method for this separation. Rhodium has been increasing in scientific and industrial importance for the past few years, with consequent increase in demand for a method for its determination. Preliminary experiments on a proposed method have been completed, and a systematic study is in progress.

Preparation of pure metals.—Some additional work was done on the purification of rhodium. This section cooperated with the division of metallurgy in its additional work on the preparation of the 10 per cent rhodium—90 per cent platinum alloy. Other work on purification consisted largely of the routine preparation of the va-

rious metals as needed. About 1,500 grams of pure platinum was prepared for use in the various investigations in progress and for issue to other sections of the bureau in the form of thermocouples. In a few cases platinum wire was issued in small quantities to outside laboratories where the highest purity was essential. About 150 grams of pure palladium was prepared for the heat division. One sample of a pure palladium salt and one of a pure iridium salt were issued to an outside laboratory.

Miscellaneous.—In addition to the specific projects already discussed, numerous minor studies were made on chemical and physical properties of the platinum metals. A bibliography of the metals of this group, commencing with 1918, was brought up to date. This is to supplement the bibliography published by the United States Geological Survey, which is complete through 1917. In cooperation with the division of metallurgy a paper describing the scope and purposes of the bureau's work on the platinum groups was published in the Transactions of the American Electrochemical Society.

Chemical Reagents and Apparatus (Isaacs).

The examination of all reagent chemicals purchased by the bureau was continued during the year. Eighty-five lots of reagents were analyzed. In general, an improvement was noted in the quality of such chemicals over those purchased in previous years. There still remains a need for a study of methods used in testing reagents. Lack of funds has so far made any systematic work in this field impossible, and only a very limited amount of time could be applied to the problem during the year.

About 600 pounds of mercury was purified for use in the bureau's laboratories, as well as a small quantity of sodium chloride, which was specially prepared for the division of weights and measures.

Some attention was given to the improvement of analytical glass funnels, one of the makers of glass apparatus cooperating.

6. ELECTROCHEMISTRY.

William Blum.

The principal work of this section consists of investigations upon the electrodeposition of metals. In addition, assistance is frequently rendered to other sections of the bureau in connection with such measurements as conductivity and hydrogen-ion concentration.

The purposes of the studies upon electrodeposition are (a) to determine the fundamental principles, especially those which govern the structure and properties of the deposits; (b) to develop methods for the analysis and control of electroplating and electrotyping solutions; and (c) to furnish to interested Government departments, manufacturers, electroplaters, and others information and advice. Owing to the fact that there are comparatively few persons with technical training connected with the electroplating and electrotyping industries, frequent visits to plants and lectures to appropriate groups are necessary and helpful. In addition to the contacts thus formed, the section keeps in close touch with the industry through the research committee of the American Electroplaters' Society which meets at the bureau twice a year. An experienced electroplater, George B. Hogaboom, is employed in an advisory capacity.

General Electrodeposition.

Current distribution and "throwing power" (Haring).—In commercial electroplating it is important to secure as nearly uniform distribution of the metal coatings as possible, especially upon irregularly shaped articles. Solutions which produce good distribution are popularly designated as having good "throwing power." This property has been defined and methods of measuring and controlling it have been devised. These experiments were made with copper solutions. A study of throwing power in nickel deposition is in progress.

Structure of deposits (with metallurgical division).—The internal structure of electrodeposits is important because it largely determines those properties, such as hardness, strength, ductility, and luster, upon which the usefulness of the coatings depends. Investigations thus far conducted have led to the development of a tentative theory of the mechanism of metal deposition and of a simple classification of the crystal types existent in electrodeposits. Further work is required before definite conclusions can be reached.

Effect of base-metal structure (with metallurgical division).—It has been found that when copper is deposited upon rolled or cast copper under certain conditions the crystals of the electrodeposit are direct continuations of those existing in the base metal. This observation indicates the possibility of similar effects when one metal—for example, nickel or silver—is plated upon another, such as steel, brass, or nickel-silver. It is hoped that this subject may be investigated further.

Nickel Deposition.

Acidity (Thompson).—Further observations have indicated the usefulness of hydrogen ion (or pH) measurements for controlling the acidity of nickel solutions both in research and in practical electroplating.

Effects of impurities (Thompson, Thomas).—The principal metallic impurities likely to be present in nickel salts are copper, zinc, and iron. Copper was found to be most detrimental, and zinc slightly less so, while iron in moderate amounts is not usually deleterious. On the basis of this information and of an examination of a large number of samples of commercial nickel salts tentative specifications have been prepared.

Nickel anodes (Thomas and metallurgical division).—A satisfactory technique has been developed for measuring quantitatively the corrosion efficiency of nickel anodes; that is, their ability to maintain the nickel content of the solutions. Preliminary experiments have been completed and final tests are now in progress to determine the effect of the composition, method of preparation, and structure of nickel anodes upon their behavior.

Conductivity (Hammond).—The conductivity of solutions containing nickel sulphate and the various common constituents of nickel baths have been determined.

Deposition of nickel on zinc (Thompson).—An investigation has just been started to determine the best conditions for nickel plating upon zinc and die castings. Difficulty is now frequently experienced in obtaining commercially satisfactory adherent deposits.

Preparation of pure nickel (Thompson).—Experiments are in progress to produce on a fairly large scale nickel of very high purity suitable for the determination of the physical constants.

Specifications for nickel plating (Sager).—At the request of the Federal Specifications Board the thickness of the nickel coatings on a number of plumbing fixtures was determined. A tentative specification, based upon a minimum average thickness of nickel, has been prepared and is now under consideration.

Platinum Deposition (Bailey).

A study of platinum deposition is being made in order to define, if possible, conditions which would yield dense, impervious deposits of platinum which will protect the base metal from the action of corrosive liquids or gases. Preliminary results indicate that most platinum deposits, such as are applied to jewelry, are porous and exert little protective action.

Electrolytic Alteration of Copper Map Plates (Bailey).

At the request of the U. S. Coast and Geodetic Survey a method has been developed by which alterations may be made upon engraved copper plates with a considerable saving in time and labor over previously used methods. The operation depends upon a process devised by a member of the bureau's staff, whereby metal can be deposited by means of a stream projected from a nozzle in which an anode is contained. Similarly, it is possible to dissolve metal from a given surface by a reverse current. In either case action occurs only at the point where the projected stream strikes the plate and not upon the surrounding area over which the liquid flows. In the correction of map plates the copper is first dissolved by this method from the area to be corrected and may then be redeposited to the desired thickness, or the dissolved area may be brought up to the desired plane by hammering the back of the plate, and copper may then be deposited on the back of the plate if necessary.

7. GAS CHEMISTRY.

E. R. Weaver.

Methods of purification, analysis, and testing of gases, including illuminating gas and special gases, such as hydrogen, oxygen, nitrogen, and argon, comprise the chief work of the section of gas chemistry.

The work of the section has been carried on during the past year almost entirely upon funds transferred from other departments, particularly the Army and the Navy. Much of the work has been of a routine nature, including the testing of balloon fabrics and the construction and calibration of instruments of various kinds previously developed within the section. Partly for this reason the research work has been more than usually fragmentary, and no outstanding projects have been carried out, but the important researches of the previous year have been completed and preliminary work has been done upon several new undertakings of the utmost importance.

Although the financial support of the section has come largely from military sources, none of the problems dealt with has been

military in a technical sense, since all have been of an industrial character. The success which has been attained in the solution of the problems of the small industries operated within the Government departments indicates the importance of extending the investigations and of applying the results already obtained to larger fields of industry. Even in case the results of a given investigation are not directly applicable to industry the experience gained and the facilities developed for research work can be applied immediately and effectively to the solution of industrial problems.

Assembling Technical Information.

The section constantly acts as a consultant to other agencies of the Government and to the general public on all sorts of technical questions relating to gases. An important part of the work of the section is the preparation and publication of summaries of the available knowledge on special branches of gas technology. Successful work of this character is made possible only by the systematic review and indexing of the scientific literature relating to the physical and chemical properties of all the important gases, gas analysis, and the methods of producing, separating, purifying, and handling gases for all purposes. A large amount of time is necessarily devoted to library work of this character.

During the past year Circular No. 81, entitled "Bibliography of the Scientific Literature Relating to Helium," was revised and about 200 references added.

Much work was done upon a critical review of the existing knowledge of the densities and the pressure-volume temperature relations of gases (Pickering). The sections on densities and on critical constants were completed. About three-quarters of the work on the review of thermal expansion and compressibility is done. After the selection of the most reliable data is completed much work will remain to be done upon the construction of tables and charts and the written discussion. A special effort will be made to present the subject in such a way that the use of the most accurate data available will be possible for the reader without technical training. This work will have immediate application in the measurement and sale of gases and should have many other industrial uses.

General Gas Analysis (Ledig, Shepherd).

Less than the usual amount of time has been devoted to the study of general methods of gas analysis because of the small number of men in the section, the demands of other problems, and the need for gases of known purity in carrying on the investigation. A new type of burette and compensator is being developed, which it is hoped will be nearly as accurate as the weight burette, previously developed in the section, and will permit much more rapid work.

Automatic Gas Analysis (Palmer).

Development work upon the analysis of gases by the thermal conductivity method has continued, but the many demands from various Government laboratories for the construction and calibration of apparatus of this type have prevented the bureau from devoting as much time to this problem as is desirable.

The development of convenient apparatus for determining the permeability of balloon fabrics without removal from the balloon

and for determining the purity of balloon gas was completed and two sets of apparatus of each type were built and calibrated for other departments of the Government. Similar kinds of automatic apparatus constructed for other Government establishments were as follows: Four helium indicators, 3 helium recorders, 1 recorder for sulphur dioxide in the exit gases from a sulphuric acid plant, 1 apparatus for determining ammonia, and 1 for analyzing mixtures of nitrogen and hydrogen.

The small amount of research work for which time was available resulted in the development of improved methods for controlling the temperature of and the current supplied to the gas-analyzing units and of a practical cell for analyzing gases containing chlorine. A more thorough study was made of the effect of certain physical conditions upon the performance of the thermal-conductivity apparatus, particularly the effects of gas pressure and of applied voltage.

A general paper on the method has been prepared which covers quite completely the construction, calibration, and uses of the instruments employed.

Preliminary work has been done upon two new forms of apparatus for detecting hydrogen in submarines. Both are believed to be much better suited to severe service conditions than the detector formerly developed.

The method is rapidly assuming a position of importance in several industries, largely through the efforts of the bureau to introduce the method to the public. Five instrument companies in this country are now making, or preparing to make, commercial apparatus of this type.

Absorption of Gases (Ledig).

An investigation has been in progress for some months upon the fundamental phenomena of the absorption of gases in liquids, including both physical solution and chemical reactions. The ultimate object of the research is to secure complete engineering data by which the performance of any commercial absorbing unit can be computed from a laboratory test upon the gas and liquid to be used. This is pioneer work which has required the development of entirely new methods of study. The investigation has progressed as far as a practically complete qualitative explanation of the phenomena involved, and some work has been done toward the quantitative application of the results to engineering problems.

Hydrogen Production.

The investigation of methods of producing hydrogen for aeronautical purposes, which was the major project of the preceding year, has been practically completed as far as its application to aeronautics is concerned. A plant to supply Scott Field is now being constructed by the Air Service according to specifications furnished by the section. This plant will make hydrogen by the thermal decomposition of oil, which is the process best adapted to the intermittent production of hydrogen on a moderately large scale. The work of the section upon the steam-iron process resulted in the development of an essentially new method of hydrogen manufacture which gives promise of great industrial possibilities. These possibilities have as yet not been thoroughly studied.

A description of the oil-cracking process has been published in an outside journal. A comprehensive publication on the hydrogen investigations of the bureau is in preparation. This paper will deal at length with the possibilities of future development resulting from the investigations as well as with the researches themselves.

Water Detector (Ledig).

To meet an important need in the refrigeration and chemical industries the section has developed a detector for water vapor, intended particularly for use in closed pipes, which depends upon the electrical conductivity of a thin film of a hygroscopic electrolyte. With this detector it is possible to record water vapor with considerable accuracy, but any one instrument in its present stage of development will operate successfully over only a small range of vapor pressure. By providing for automatic temperature control it appears feasible to make an instrument which will operate successfully over a wide range of humidities. Preliminary work has been done on this instrument of wider range.

Apparatus for Fractionation and Low-Temperature Experiments (Shepherd).

An elaborate apparatus is in the course of construction for the analytical separation of gases and their purification in experimental quantities by low-temperature distillations. The apparatus includes several novel features which have been developed within the section, one of which is a sample-collecting vacuum pump of large capacity. In addition to its uses for analysis and purification, the apparatus should be useful for the study of vapor pressures, solubility, adsorption, and other phenomena, particularly in liquefied gases. A part of the apparatus has already been used to prepare helium of spectroscopic purity.

Gasoline in Natural Gas (Shepherd).

One of the major problems for which the apparatus mentioned in the preceding paragraph is to be used is the study of methods of determining gasoline in natural gas. The bureau is represented on the committee appointed by the Natural Gas Association to standardize this determination, which is of great importance both as an aid to engineering practice and as an essential part of many of the contracts between the gas producers and companies separating the gasoline. Much work has been devoted to a study of the natural gas-gasoline industry in connection with this problem.

Miscellaneous.

Among the numerous minor activities of the section may be mentioned the following:

A discussion of the airship slide rule developed by the section was prepared for publication and will appear in the Eighth Annual Report of the National Advisory Committee for Aeronautics (Pickering).

Apparatus was devised and used for determining whether the static sparks produced by pulling apart balloon fabrics would ignite mixtures of hydrogen and air (Pickering).

A set of standard paper strips impregnated with lead acetate and exposed to known small amounts of hydrogen sulphide was prepared

for the use of another section of the bureau in studying the corrosion of concrete in sewers. Preparing strips of uniform color with known amounts of gas proved a rather troublesome problem, requiring the development of new methods. The standards finally prepared were used with success (Shepherd).

The routine testing of 240 balloon fabrics, of calcium carbide, and a few other materials of miscellaneous character has consumed much time.

Important Problems Upon Which Preliminary Work Has Been Done.

Many possibilities for important industrial developments have grown out of the past work of the section. In several cases preliminary work has been done to determine the probable feasibility of the various projects.

The work on automatic gas analysis has opened up a large field for study and development in the automatic control of many industrial processes. The simplest, and probably the most important of these, is a system of efficient control of boiler firing by a combination of temperature measurements and gas analysis which has been worked out in some detail but not yet tried experimentally.

Much preliminary work has been done upon a new type of multiple electrical recorder capable of taking a large number of practically simultaneous records, operating any desired number of indicating instruments, and performing several other operations, including integration and the operating control of automatic machinery. An electrical method of recording pressures has been developed and tried successfully in the laboratory. A method for recording directly any one of a wide variety of simple functions of several variables, each of which can be measured independently, has been worked out theoretically, and some details regarding which there was doubt have been worked out. The method promises to have many important applications, among them the recording (and, if desired, integrating) of orifice meter measurements directly in gas volumes corrected to standard conditions of temperature and pressure, and the recording of the heating value of a gas likewise corrected.

The production of hydrogen as a by-product of city gas works, by oil refineries, and from natural gas are promising prospects which may contribute to the solution of the fixed nitrogen problems.

The simultaneous production of gas and electrical power is an equally promising field for study.

The hydrogen investigations have shown the need for, and some of the laboratory developments have shown the way to carry out, a fundamental study of many of the more important industrial gas reactions, particularly with respect to rates.

CHEMICAL TESTING.

The number of chemical tests made in the laboratories of the chemistry division during the fiscal year was 8,506. Distributed by types of materials the tests were as follows:

Ferrous metals (irons and steels)_____	612
Nonferrous metals, alloys, and coated metals_____	696
Cement and cement materials_____	1,464
Bituminous products (including creosotes, etc.)_____	545

Varnish materials (including shellacs)-----	533
Paint materials-----	711
Lubricants-----	640
Soaps, nondrying oils, and metal polishes-----	531
Inks and related office supplies-----	962
Balloon fabrics, etc-----	305
Rubber-----	699
Textiles-----	404
Miscellaneous-----	404
Total-----	8,506

These tests were made for very many Government bureaus and establishments and for States, municipalities, and private parties, as follows:

Agriculture-----	20
Commerce (this includes samples received from other divisions of the bureau for chemical tests)-----	3,591
Interior-----	55
Labor-----	3
Navy-----	601
Post Office-----	908
Treasury-----	375
War-----	482
United States commissions and committees (including U. S. Shipping Board)-----	700
General Supply Committee-----	750
Panama Canal-----	882
Other independent establishments-----	103
State and municipal-----	59
Private parties-----	77
Total-----	8,506

PUBLICATIONS.

The following papers, circulars, and letter circulars, emanating wholly or in part from the chemistry division, were published during the year:

Composition, purification, and certain constants of ammonia (E. C. McKelvy and C. S. Taylor), Sci. Paper No. 465; Refrig. Eng., 9, p. 213; 1923.
 Specific volume of saturated ammonia vapor (C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor), Sci. Paper No. 467; Refrig. Eng., 9, p. 239; 1923.
 Shellac (P. H. Walker and L. L. Steele), Tech. Paper No. 232.
 Bibliography of scientific literature relating to helium (E. R. Weaver), Circular No. 81, second edition.

The following United States Government specifications for paints and paint materials, all prepared by the technical committee on paints of the Federal Specifications Board, P. H. Walker, of the Bureau of Standards, chairman:

Linseed oil, raw, refined, and boiled, Circular No. 82, second edition.
 Basic carbonate white lead, dry and paste, Circular No. 84, second edition.
 Basic sulphate white lead, dry and paste, Circular No. 85, second edition.
 Turpentine, Circular No. 86, second edition.
 Zinc oxide, dry and paste, Circular No. 87, second edition.
 Lead zinc oxide, dry and paste, Circular No. 88, second edition.
 White paint and thinned paints made on a white base, semipaste and ready mixed, Circular No. 89, second edition.
 Ocher, dry and paste, Circular No. 91, second edition.
 Iron-oxide and iron-hydroxide paints, Circular No. 93, second edition.
 Black paint, semipaste and ready mixed, Circular No. 94, second edition.
 Green paint, semipaste and ready mixed, Circular No. 97, third edition.
 Volatile mineral spirits for thinning paints, Circular No. 98, second edition.

Composite vehicle for thinning semipaste paints when the use of straight linseed oil is not justified, Circular No. 102, second edition.
Water-resisting spar varnish, Circular No. 103, third edition.
Asphalt varnish, Circular No. 104, second edition.
Liquid paint drier, Circular No. 105, second edition.
Flat interior lithopone paint, white and light tints, Circular No. 111, second edition.
Interior varnish, Circular No. 117, second edition.
United States Government specifications for fire-extinguishing liquid (F. W. Smither), Circular No. 134.
Soap (F. W. Smither, P. H. Walker, and J. H. Bower), Circular No. 62, third edition.
Acid-proof coatings for concrete surfaces, Letter Circular No. 42, third edition.
Effect of Su-Dex process of treatment on physical properties of several woods, Letter Circular No. 53.

The following United States Government specifications for soaps, all prepared by the technical committee on soaps of the Federal Specifications Board, F. W. Smither, of the Bureau of Standards, chairman:

White floating soap, Circular No. 123.
Liquid soap, Circular No. 124.
Soap powder, Circular No. 125.
Salt water soap, Circular No. 126.
Automobile soap, Circular No. 127.
Chip soap, Circular No. 128.
Ordinary laundry soap, Circular No. 129.
Grit cake soap, Circular No. 130.
Scouring compounds (*a*) and (*b*) for floors and soap-scouring compounds (*c*), Circular No. 131.
Hand grit soap, Circular No. 132.

The following appeared during the year in outside journals:

Standard methods for the sampling and analysis of commercial soaps and soap products. Report of a committee of the industrial division, American Chemical Society, of which P. H. Walker, of the Bureau of Standards, was a member. *Jour. Ind. and Eng. Chem.*, 121, p. 1159; 1922.
Effect of impurities in nickel salts used for electrodeposition (M. R. Thompson and C. T. Thomas), Letter Circular No. 83 and *Trans. Amer. Electrochemical Soc.*, 42; 1922.
The influence of the base metal on the structure of electrodeposited metals (W. Blum and H. Rawdon), *Trans. Amer. Electrochemical Soc.*, 43; 1923.
Some physical properties of paints (P. H. Walker and J. G. Thompson), *Proc. Am. Soc. Testing Materials*, 22, P. III, p. 464; 1922.
Separation of iron and aluminum from manganese and certain other elements (G. E. F. Lundell and H. B. Knowles), *Jour. Am. Chem. Soc.*, 45, p. 676; 1923.
The production of hydrogen by the thermal decomposition of oil (E. R. Weaver), *Chem. and Met. Eng.*, 28, pp. 764, 939, and 1072; 1923.
Notes on the determination of phosphorus (G. E. F. Lundell and J. I. Hoffman), *Jour. Ind. Eng. Chem.*, 15, pp. 44 and 171; 1923.
Investigations on platinum metals at the Bureau of Standards (E. Wichers and L. Jordan), presented at the forty-third general meeting of the American Electrochemical Society, New York, May, 1923.
Current distribution and throwing power in electrodeposition. (H. E. Haring and William Blum); presented at the forty-third general meeting of the American Electrochemical Society, New York, May, 1923. (*Trans. Amer. Electrochemical Soc.*, 43, 1923.)
Effect of iron on the electrodeposition of nickel (M. R. Thompson), *Trans. Amer. Electrochemical Soc.*, 43; 1923.

The following are in press or preparation:

Atomic weight of osmium (R. Gilchrist), Doctoral thesis, Johns Hopkins University.
Analysis of chrome-vanadium steel (G. E. F. Lundell, J. I. Hoffman, and H. B. Knowles).

An airship slide rule (E. R. Weaver and S. F. Pickering).

A detector for water vapor in closed pipes (E. R. Weaver and P. G. Ledig).

A review of the densities of various gases (Marion Smith Blanchard).

A review of the critical constants of various gases (S. F. Pickering).

Thermal conductivity method for the analysis of gases (P. E. Palmer and E. R. Weaver).

The development of an improved steam-iron process for the production of hydrogen (E. R. Weaver and A. H. Graham).

Determination of total sulphur in rubber goods (S. Collier, M. Levin, and R. T. Mease).

The interference of cobalt and certain other elements in the bismuthate method for manganese (G. E. F. Lundell).

Notes on the crystalline form of electrodeposited metals (William Blum and H. S. Rawdon).

The determination of iridium in platinum alloys by the method of fusion with lead (Raleigh Gilchrist).

MECHANICS AND SOUND.

L. J. Briggs.

FUNCTIONS.

Investigations relating to mechanics, sound, and properties of matter, including hydrodynamics, aerodynamics, aircraft and engineering instrument research, and the standardization of mechanical appliances; embracing investigations of sound ranging, sound-proofing properties of building materials, analysis and correction of acoustical defects of auditoria, time-signaling apparatus, elastic properties of diaphragms and springs, testing and development of aircraft and engineering instruments, ballistics, wind tunnel tests and research, and development and standardization of plumbing systems, builders' hardware, and elevator safety interlocks.

SECTIONS.

1. Engineering instruments and appliances.
2. Sound measurements.
3. Aeronautic instruments.
4. Aerodynamical physics.

GENERAL STATISTICS.

Staff	48
Expenditures (1922-23)	\$151,000
Tests completed	870
Researches completed	58
Bureau publications	4
Other technical publications	13

WORK CHART.

SPECIAL INVESTIGATIONS.

SCOPE.

Special investigations on mechanics and properties of matter.
Standardization of mechanical appliances.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
High-pressure steam-heating lines.....	100	Outside. ¹
Rate of exhaustion of closed tank.....	100	T224.
Jet propulsion of airplanes.....	100	Outside. ²
Leakage through thin clearance spaces.....	100	Do. ³
Relative wearing value of ball-bearing and steel bushed bronze butts.....	100	Do. ⁴
Earth inductor compass.....	80	
Precision weighings of large crystals.....	80	
Gravitational constant.....	10	
Gyroscopic stabilization.....	70	
Dimensional theory.....	Continuing.	
Orifice meter research.....	50	
Crystal structure.....	10	
Carrying capacity of soil stacks.....	50	
Plumbing traps.....	30	
Builders' hardware specifications.....	80	

¹ Mechanical Engineering, October, 1922.

² N. A. C. A. report 159, 1923.

³ Engineering, Feb. 23, 1923.

⁴ Hardware Age, Mar. 31, 1923.

1. ENGINEERING INSTRUMENTS AND MECHANICAL APPLIANCES.

SCOPE.

The calibration of engineering instruments.
The study of theory, characteristics, and limitations of engineering instruments.
The development and improvement of engineering instruments.
The development and improvement of methods of calibration.
The formulation of standards of performance for engineering instruments.
The investigation of groups of similar commercial appliances for the purpose of establishing standards of performance.
The development of test methods and apparatus.
The investigation of new appliances of engineering importance.
The testing of mechanical appliances.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Current meters.....	376	455
Pressure gauges.....	200	208
Anemometers.....	15	17
Miscellaneous (instruments).....	11	8
Radiator valves.....	9	5
Fire extinguishers.....	25	33
Miscellaneous (appliances).....	9	10

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Safety release devices, hydrogen cylinders:			
Fusible plugs.....	Army.....	100	Outside. ¹ Do. ¹
Frangible disks.....	do.....	95	
Performance of commercial odometers.....	do.....	15	
Elevator interlocking devices.....		50	
Radiator traps.....		100	
Anemometers.....		100	
Allen hydraulomat.....		30	
Fire extinguishers (new types):			
Foam.....		100	
Carbon tetrachloride.....		100	
Soda and acid.....		100	
Calcium chloride.....		100	
Radiator valves (new types).....		100	
Thermostatic valves.....		100	

¹ Jour. Am. S. H. V. E., March, 1923.

2. SOUND MEASUREMENTS.

SCOPE.

Sound sources.

Sound receivers.

Acoustic properties of materials.

Frequency standardization.

Oscillography.

Chronography (involving time intervals of less than one second).

Ballistic measurements.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Frequency.....	7	11

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Acoustics of rooms.....		100	Outside. ¹
Sound-transmission experiments.....		10	S473.
Voice-tube experiments.....	Navy.....	50	
Electric-clock form.....		50	
Long-wave radio recorders.....	Coast and Geodetic Survey.	100	
Short-wave radio recorder.....	Army.....	100	
Do.....	Coast and Geodetic Survey.	100	
Radio-acoustic method of position finding.....	do.....	50	
Motor-driven chronograph.....	do.....	65	
4-inch high-speed oscillograph camera.....	Navy.....	100	
8-inch high-speed oscillograph camera.....	Army.....	100	
Piezo-electric blastmeter.....	do.....	100	
10-inch Piezo-electric blastmeter.....	do.....	90	
Homopolar velocimeter.....	do.....	100	
Small-arms retardation chronograph.....	do.....	100	
Solenoid spark chronograph.....	do.....	85	

¹ Jour. Franklin Inst., June, 1923.

3. AERONAUTIC INSTRUMENTS.

SCOPE.

Researches on errors of aeronautical instruments, theory of their performance, temperature compensation, etc.

Researches on instrument diaphragms and diaphragm materials.

Investigation of flat and helical springs for instruments.

Investigation of aerial navigation methods.

Development of testing methods for aeronautic instruments.

Standardization of aeronautical instruments.

Preparation of specifications for aeronautical instruments.

Investigation of sphygmomanometers.

Development of altitude instruments.

Development of rate-of-climb instruments.

Development of power plant instruments.

Development of air-speed instruments.

Development of special instruments for lighter-than-air craft.

Development of navigating instruments.

Development of surveying and engineering aneroid barometers.

Development of special mercurial barometers.

Development of salvage methods for aeronautic instruments.

Determining altitudes for record flights.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Aerial sextants.....		2
Air-speed indicators.....	24	14
Altimeters.....	26	21
Aneroid barometers.....	10	3
Barographs.....	5	16
Surveying aneroids.....		4
Mercurial barometers.....	3	3
Rate-of-climb indicators.....	10	
Air-pressure gauges.....	1	
Oil-pressure gauges.....	1	
Manometers.....	1	
Sphygmomanometers.....	5	16
Tachometers.....	16	18
Turn indicators.....	11	3
Airplane thermometers.....	3	

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Investigation of instrument diaphragms:			
Elastic properties of metallic diaphragms.....	N. A. C. A. and Army.....	85	Outside. ¹
Tension experiments on metallic diaphragms.....	N. A. C. A.....	80	
Investigation nonmetallic diaphragms.....	N. A. C. A. and Army.....	75	
Drift and hysteresis in metallic diaphragms.....	Army.....	100	
Investigation of barometric syphon diaphragms.....	do.....	100	
Investigation of Bourdon tubes:			
Development of theory.....	N. A. C. A.....	80	
Elastic and temperature errors Bourdon tubes.....	Army.....	95	
Investigation of bimetallic bars.....	do.....	25	
Determination of altitude of aircraft.....	N. A. C. A.....	100	
Investigation of night and cloud flying.....	do.....	95	
Investigation of aerial navigation.....	do.....	95	
Investigation of methods for reducing astronomical observations.	Army.....	100	
Investigation of aircraft compasses.....	Navy.....	100	
Investigations of aerial sextant.....	Army.....	100	
Investigation of gasoline-flow meters.....	Navy.....	100	
Investigation of springs for instruments.....	do.....	25	
Theory of rate-of-climb indicators.....	do.....	10	
Investigation of aeronautic instruments.....	do.....	100	T237.
Development of ground-speed and drift indicator.....	Army.....	100	
Development of distant indicating tachometer.....	do.....	100	
Development of electric turn indicators.....	do.....	100	
Development of electric turn meter.....	Navy.....	100	
Development of horizontal angle indicator.....	Army.....	95	
Development of precision barometer.....	do.....	100	
Development of precision altimeter.....	do.....	90	
Development of precision barograph.....	do.....	85	
Development of temperature-compensated altimeter, expansion thermal element.	Navy.....	30	
Development of temperature-compensated altimeter, bimetallic thermal element.	do.....	100	
Development of temperature-compensated thermobarograph.	Army.....	60	
Development of open scale landing altimeters.....	Navy.....	75	
Development of precision surveying aneroid barometer.	do.....	100	
Design of portable mercurial barometers.....	Army.....	10	
Development of mechanical statoscope.....	do.....	100	
Development of improved rate-of-climb indicator.....	Navy.....	90	
Development of improved liquid rate-of-climb indicator.	do.....	90	
Development of combined statoscopes and rate-of-climb indicators.	Army, Navy....	90	
Development of high-speed airspeed indicators.....	Navy.....	100	
Development of suspended head electric airspeed indicators.	do.....	95	
Development of gas-pressure alarm.....	do.....	100	
Development of ballonet volume indicator.....	Army.....	100	
Development of fabric tensionmeter.....	Navy.....	75	
Development of mine-depth recording instrument....	do.....	100	
Development of aircraft compass.....	do.....	85	

¹ N. A. C. A. Tech. Rept. No. 165.

4. AERODYNAMICAL PHYSICS.

SCOPE.

Measurement of the resistance of the air to the motion of bodies relative to it, including the determination of the magnitude, direction, and point of application of the resultant force, its relation to the relative speed, and the force distribution over the surface of the body: (a) Measurement of forces and moments on airfoils, airplane models, aircraft bombs and bomb models, airship models, etc., (b) measurement of the damping of oscillations of bombs, airship models, etc., (c) measurement of the distribution of pressure over airship hulls, airship fins, projectiles, etc., (d) measurement of wind pressure on structures.

Calibration of instruments for use in air-streams of speeds ranging from 15 to 150 miles per hour.

Study of the steadiness of air-streams used for the above-mentioned measurements.

Study and development of wind tunnel apparatus and methods.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Airspeed meters.....	18	9
Airfoils.....	2	1
Aircraft models.....	1	1
Turn indicators.....	3	4
Miscellaneous.....		8

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Pressure distribution over the military airship hull..	Army.....	100	
Forces and moments on the military airship.....	do.....	100	
Shielding effect of car on military airship.....	do.....	100	
Forces and moments on type A. P. high altitude observation balloon.....	do.....	100	
Comparative tests of four Goodyear hull models.....	do.....	100	
Pressure distribution over the RS-1 airship hull.....	do.....	100	
Forces and moments on the RS-1 airship hull with 12 sets of fins, control surfaces neutral.....	do.....	100	
Forces and moments on the RS-1 airship hull with 2 sets of fins, control surfaces at angles.....	do.....	100	
Damping coefficients for RS-1 airship hull with 12 sets of fins, control surfaces neutral.....	do.....	100	
Damping coefficients for RS-1 airship hull with 2 sets of fins, control surfaces at angles.....	do.....	100	
Effect of presence of fins on pressure distribution over RS-1 airship hull.....	do.....	80	
Study of discrepancies of check runs on stream line models.....	do.....	20	
Effect of tunnel leakage on pressure drop.....	do.....	10	
Scale effect on airship hulls.....	do.....	10	
Characteristics of oscillating apparatus.....	do.....	50	
Damping coefficients of aircraft bomb models.....	do.....	90	
Forces and moments on Loring D500 bomb model.....	do.....	100	
Comparative measurements on model and full scale bomb.....	do.....	100	
The relation of the center of area of meridian section of aircraft bombs to center of pressure.....	do.....	25	
Absolute measurement of velocity of air streams.....	N. A. C. A.....	50	
Direct check of Pitot tube.....	do.....	100	
Speed fluctuations in Venturi type wind tunnel.....	do.....	25	
Performance of roof ventilators in wind stream normal to axis of ventilator.....	do.....	100	
Wind forces on two automobile models.....	do.....	100	
Shielding of electric power lines on same cross arm.....	do.....	10	

Detailed Report of the Year's Work.

GENERAL.

The mechanics and sound division includes sections dealing with (1) engineering instruments and mechanical appliances, (2) sound investigations, (3) aeronautic instruments, and (4) aerodynamical physics. In addition, special experimental and theoretical researches and problems relating to performance standards of mechanical appliances are carried on by a staff of engineering physicists. The activi-

ties of the division in testing and research are described in the following pages. An equally important feature of the work is to be found in the advisory relationships which have been established with other technical branches of the Government and with the industries. This is illustrated by the participation of the bureau (1) in the formulation of several of the power-test codes of the American Society of Mechanical Engineers and in the work of the American Engineering Standards Committee and the A. S. M. E. Fluid Meters Research Committee; (2) in the work of the aerodynamics committee of the National Advisory Committee for Aeronautics; (3) in numerous conferences with representatives of the Army and Navy, particularly in connection with problems in aerodynamics, ballistics, and aerial navigation; and (4) in the work of the building code committee of the Department of Commerce and the builders' hardware committee of the Federal Specifications Board.

1. ENGINEERING INSTRUMENTS AND APPLIANCES.

W. F. Stutz.

Current Meter Rating Station (Lewis, Graff).

The calibration of water-current meters, instruments used in the measurement of the quantity of water flowing in rivers and other open channels, requires the use of a body of still water of considerable length and means for towing the instruments at different uniform speeds. An adequate installation for this purpose is too extensive and costly to be provided by private enterprise. An hydraulic laboratory designed and equipped especially for this purpose, and in continuous operation throughout the year, is maintained by the bureau to supply this important engineering need. During the past fiscal year 455 current-meter calibrations were made for the different engineering bureaus of the Government, instrument manufacturers, and engineers in private practice.

Calibration of Instruments (Hodge, Lewis, Graff).

A total of 688 engineering instruments were calibrated during the year, including 455 current meters, 208 pressure gauges of various descriptions, 17 anemometers, and 8 miscellaneous instruments.

Performance Tests of Odometers.

At the request of the Motor Transport Corps of the Army an investigation of the performance of commercial types of odometers has been undertaken. A machine for approximating the conditions of road service has been constructed, and the first tests of commercial devices are about to be made.

Radiator Return Line Valves (Stutz, Lewis).

The successful operation of the heating system generally installed in public buildings is primarily dependent on the performance of thermostatic valves placed at the outlet of each radiator. At the request of the Supervising Architect of the Treasury Department a series of performance tests was made of all such valves presented to that office for its approval for use in buildings under its jurisdiction. To pass these tests successfully the valves must comply with performance specifications developed as a result of a previous investi-

gation of a large number of such devices. Five series of tests of this character were made during the past year. The data resulting from such tests are also employed by other Government departments.

Fire Extinguishers (Lewis, Bailey).

At the request of the Steamboat Inspection Service tests and investigations were made of 33 hand chemical fire extinguishers for the guidance of the Board of Supervising Inspectors.

Miscellaneous Engineering Tests.

A number of engineering tests of a miscellaneous nature were made during the year, such as hydrostatic tests of pressure vessels, condenser testing, tests of valves, and the like.

Investigation of Elevator Safety Devices (Stutz, Bailey, Buynitzky).

The investigation of elevator interlocking devices begun near the close of the last fiscal year, at the request of the city of Baltimore, has been continued through the present fiscal year. A study of elevator accident statistics shows that about three-fourths of the accidents fatal to the public occur at the hoistway door. A well-designed and reliable interlocking device would practically eliminate accidents of this character, and appreciation of this fact is leading to the rapid extension of the compulsory use of such devices. However, their approval by regulatory bodies has been based largely on a visual inspection, and it is the purpose of this investigation to obtain experimental data which will permit the basing of such approval upon the results of actual reliability performance tests. A series of such tests, including an endurance reliability test under normal conditions of operation, a test in a corrosive atmosphere, in a dust-laden atmosphere, operation without lubrication, and under conditions of misalignment likely to occur in practice, has been developed and automatic apparatus for conducting the tests completed. Nine commercial devices have been tested. The outstanding results of the investigation thus far conducted are: First, the proof of the need of performance tests for such devices; and, second, the necessity for improvement of available devices. Of the interlocks on the market at the time the investigation was undertaken the number which could comply with a reasonable performance requirement was very small, indeed. The majority of the interlocks tested have been or are in process of being redesigned to correct defects which developed in the tests.

Safety Release Devices for Hydrogen Cylinders (Hodge).

An investigation of safety release devices for hydrogen cylinders in progress during the last fiscal year was continued at the request of the Chief of the Air Service of the Army. The premature release under normal conditions of the devices which have been in use has resulted in serious loss of gas. One solution of the problem was found in a safety device employing a light frangible disk supported by a fusible alloy plug. The investigation was extended to include a study of unsupported frangible disks and, in particular, their behavior under continued loading. The experimental work of this investigation has been practically completed, and a report of the results of the investigation is in preparation.

2. SOUND MEASUREMENTS.

E. A. Eckhardt.

Sound-Intensity Measurements (Eckhardt, Karcher, Chrisler).

The experimental determination of the sound-transmitting and sound-absorbing properties of building materials involves the measurement of relative sound intensities. In these measurements the measuring apparatus and the measuring operation must not change the thing measured by an amount which endangers the accuracy desired. This requirement is general in physical measurements, but is exceptionally difficult to meet in sound measurements. A method for measuring relative sound intensities which satisfies this requirement has been further developed. An electromechanical sound receiver is placed in the sound field. The output of this receiver is amplified, and the resulting output of the amplifier is rectified (crystal rectifier) and measured by means of a suitable galvanometer. By use of calibrated mutual inductances the calibration of the amplifier system is avoided and the measurements are strictly comparable, independent of any amplifier adjustments. The apparatus has an intensity range of 1 to 1,000,000.

The measurement of relative sound intensities has involved the development of an instrument for the measurement of the electrical power consumed by an electromechanical sound-producing instrument. The instrument developed is of the electro-dynamometer type and, used as a detection instrument, has a sensitivity of approximately 5 microwatts per millimeter at a scale distance of 1 meter. Power values of the order of a milliwatt may be determined with a probable accuracy of 1 per cent.

Sound Chamber.

The volume of inquiries from manufacturers of building materials, builders, architects, building owners, and others indicates a pressing need for information concerning the acoustical qualities of building materials. New materials appear on the market, and neither the manufacturer nor the user know definitely how effective they are acoustically. In order to provide facilities for making such information available, a sound chamber has been built which will make the needed measurements possible.

The sound chamber is built massively of concrete. Two measuring rooms are located, respectively, above and beside a source room, the latter being separated from the remaining structure by air spaces. Panel openings are so designed that the transmitting panels when sealed into position form the only bond between the two parts of the structure, excepting the common ground on which they stand. The vertical panel opening is to be used for the study of wall structures, the horizontal panel opening for the study of floor and ceiling structures. The panels are to be built 6 by 7 feet 6 inches. When the panels are sealed into position the effective transmission area will be 5 by 6 feet 6 inches. These panels are larger than any for which transmission data have so far been found. The arrangements and the program of work are such that information covering a wide range of materials and construction can be developed rather rapidly after the preliminary difficulties have been cleared up.

Auditorium Acoustics (Eckhardt, Keiser).

Analyses have been made of a number of faulty rooms and auditoria, including school assembly rooms and offices. Corrective measures are at best expensive, although in most cases substantial improvement can be assured. Analysis of the plans of a building in advance of construction can always forestall serious mistakes in the acoustical results. Several analyses of this kind were made during the year. Addresses on auditorium acoustics were made at the Brooklyn Institute of Arts and Sciences and the Franklin Institute of Philadelphia and a paper was published on the acoustics of rooms in the Franklin Institute Journal for June, 1923.

Voice-Tube Experiments (Eckhardt, Quayle).

In cooperation with the Bureau of Construction and Repair of the Navy Department a series of experiments on the sound-transmission characteristics of voice tubes and voice-tube fittings has been carried out. This work will be continued during the coming year. None of the material on this subject is as yet available for publication.

Radio-Acoustic Ranging (Eckhardt, Keiser, Eyre).

In cooperation with the United States Coast and Geodetic Survey a procedure has been worked out for determining at any moment the position of a ship with reference to known shore points. The procedure involves the sending of a sound signal through the water from the ship and the transmission of radio signals from surveyed shore stations when the sound signal arrives. The time of departure of the sound signal and the time of arrival of the radio signals are recorded on the ship. It is anticipated that a ship engaged in making depth soundings will thus be enabled to determine its position on the map irrespective of the visibility. This is important, since smooth seas which are desirable in sounding measurements are usually accompanied by fog.

In this scheme the recording of the radio signals is accomplished by means of a short-wave radio recorder of a type previously developed by the Bureau of Standards. A chronograph to provide adequate constancy of rate under shipboard conditions of operation is being developed. The development and construction of the apparatus is well advanced, and field trial of the system will probably be secured during the summer of 1923.

Electric Clock Fork (Keiser).

By a suitable combination of the electron-tube tuning-fork drive developed in the sound laboratory in recent years and a Warren synchronous motor clock the electrical counterpart of the classical Koenig clock fork has been developed. Each complete revolution of the single hand of the clock marks the completion of 3,600 vibrations of the tuning fork. A contact arrangement permits the recording on a chronograph drum of the completion of each revolution of the clock hand. Simultaneously second marks from a standard break-circuit chronometer are recorded. The instrument permits the making of all measurements which have been made with the classical instrument and avoids the mechanical difficulties presented by the high-speed escapement of the latter.

A first report on "An electron tube tuning fork drive" was prepared and published in the *Journal of the Optical Society of America* for November, 1922.

Tuning Fork Calibrations (Keiser, McNish).

The laboratory is now in a position to certify the frequencies of tuning forks with a precision which is limited only by the constancy of their performance. Some work has been done toward improving this constancy, but the results are not yet sufficiently conclusive to warrant publication.

Radio Time Signal Recorders (Eckhardt, Karcher).

The instruments developed last year have been used with success by the United States Coast and Geodetic Survey during an entire field season for recording radio time signals in connection with precise longitude determinations. The success attained prompted the inclusion of longitude determinations in a program of field work in Alaska. To assure the increased range, additional development work was done and additional recording sets provided. With one of these sets time signals from Annapolis have been successfully recorded in Alaska and longitude determinations made. It is worthy of note that this field work is carried out during the season of pronounced static disturbances, and that some of it has been done in regions in which these disturbances are exceptionally strong.

A short-wave recorder of this type has been devised for the Ordnance Department of the United States Army and has been used successfully to record the time of release of a bomb from a plane. The releasing mechanism automatically transmits a radio signal from the plane, which is recorded at the observing station. The termination of the time of flight is recorded by the use of microphones on the bombing field. The recorder makes use of a single electron tube.

A short-wave recorder has also been built for use at sea in connection with a radio-acoustic ranging project previously described. A paper on "The errors to be expected in longitude determination by radio signals caused by the sending and receiving apparatus" was presented before the section of geodesy of the American Geophysical Union.

Oscillograph Developments (Eckhardt, Quayle, Eyre, Keiser).

By the use of tungsten wire for the loop, oscillograph vibrators of the Duddell type have been made with natural frequencies as high as 16,000 cycles per second, using relatively large mirrors 0.017 by 0.060 inch. The current sensitivity of such vibrators is of the order of 30 milliamperes per millimeter, but the current capacity is quite high. The advantage of such elements is the sharpness of the break in the record when abrupt changes occur in their circuits. This characteristic makes their use especially advantageous in the measurement of very short time intervals.

The high-speed oscillograph camera developed within the last few years has been completely redesigned. This new instrument embodies the improvements which the extensive experience with the older instrument suggested. Oscillograph cameras of this type have been supplied to the proving grounds of both the Army and the Navy.

Apparatus for Ballistic Measurements.

During the past few years considerable work has been done in cooperation with the technical staff, Army Ordnance, and the Bureau of Ordnance, Navy Department. This work has consisted largely in the development of various types of apparatus for ballistic measurements, as described below.

Piezo-electric Pressure Measurements (Eckhardt, Karcher, Keiser, Eyre, McNish).

The piezo-electric gauges developed for obtaining the time-pressure relation of a discharging gun have received service trials, and the indicator diagrams obtained by their use have been carefully compared with other data obtained from the same rounds. This comparison indicates that the physical characteristics of the gauge are satisfactory, and that the form of the pressure curve is reproduced by the recording system with a satisfactory degree of faithfulness. These comparisons indicated, however, that the calibration of the gauge is uncertain in its magnitude to the extent of about 5 per cent. This uncertainty was traced to the galvanometer. Changes in its construction and in the procedure of using the galvanometer have reduced this uncertainty, so that the calibration now may be known with an accuracy of better than 1 per cent.

A number of gauges have been designed and constructed for use in securing indicator diagrams of explosive pressures. In view of the experience gained it has been possible to increase the sensitivity of such gauges by a factor of 5. The quartz plates used were first tested for their piezo-electric quality by using an electrometer as the indicating instrument. Later a vacuum tube method suggested by Professor Cady was tried. The plates are now tested with a testing machine and a ballistic galvanometer, this process being much more expeditious and reliable than any other that has been tried.

A blast meter for obtaining the indicator diagram of blast pressures near the muzzle of guns or around exploding bombs and shells has been developed during the year. The blast pressures are, in general, of much shorter duration and of less magnitude than the pressures in guns. While adequate field trials have not been made, the tests in the laboratory indicate that the instrument will give satisfactory performance.

The piezo-electric gauge galvanometer combination really provides instantaneous values of the pressure impulse, and the sensitivity of the system is properly expressed in terms of pressure impulse units. Some attention has been given to the measurement of mechanical impulses, and measurements were made of the impulse of the recoil of a machine gun and the impulse delivered by an electric riveting hammer. This is a field of application of the piezo-electric gauge which appears very promising.

Chronograph for Ballistic Measurements (Eckhardt, Karcher, Chrisler).

A projectile velocity chronograph has been developed jointly with the technical staff of the Ordnance Department, United States Army, during the last year or two. In this instrument the current developed in solenoid coil screens when a magnetized projectile passes through them is recorded by means of an oscillograph equipped with suitable time-scale apparatus. This chronograph is now being used

currently at the Aberdeen Proving Grounds. It permits velocity determinations with a precision at least ten times greater than any previously available. Since the record is photographic there is necessarily a delay in obtaining the result.

Experiments have been made with a view to combining the advantages of coil screens with the recording element of one of the older types of chronograph which make the result more immediately available. The bureau has developed a vacuum-tube relay system which when combined with coil screens and an Aberdeen chronograph recorder provides a chronograph unit having the desired characteristics. For calibers of 4.7 inches and larger this solenoid-spark chronograph operates satisfactorily now. The work at present is directed toward securing an accuracy equivalent to that of the Boulenger chronograph for 3 inches and smaller calibers.

In connection with this work a careful analysis was made of the constancy of the Aberdeen chronograph recorder. Since the governor of that instrument is of the centrifugal type, it seemed a priori that for short-time intervals which might or might not include a period of regulation an appreciable error might result even though the average speed over many periods of regulation might be constant. The result of the study indicated the constancy to be quite adequate for all purposes contemplated.

Small Arms Retardation Chronograph (Eckhardt, Chrisler).

A chronograph has been developed with interrupters of the type used in the Joly chronograph, which function to break a circuit as the bow wave of the projectile passes. The Joly instruments make use of pivots, and because of pivot friction they sometimes fail to function. To avoid this difficulty the instrument has been redesigned and a metal ribbon suspension provided. These interrupters, together with two systems of relays, one of which is of the electron-tube type, and an Aberdeen chronograph recorder, constitute the complete chronograph. The projectile passes in succession eight interrupters suitably spaced, and the instant at which each interruption occurs is recorded on the chronograph. From this record the velocity of the projectile while traversing each of the seven known distance intervals may be determined. The retardation of the projectile due to air resistance may therefore be investigated systematically with this instrument. The precision of measurement is substantially the same as that provided by the standard Aberdeen chronograph.

Homopolar Velocimeter (Eckhardt, Karcher, Chrisler, Eyre).

The instruments usually used for obtaining the velocity and acceleration of recoil of a gun give directly the relation of gun displacement and time. A single differentiation yields the velocity and a second differentiation gives the acceleration. A homopolar dynamo has been developed, which is so fastened to the gun and its carriage that its angular velocity is directly proportional to the linear velocity of the gun. The current in the dynamo circuit is recorded oscillographically. The record gives directly the velocity-time curve of recoil, and a single differentiation yields the acceleration. The calibration of the instrument is simple. Actual trial has yielded satisfactory results. The advantages of obtaining a velocity record directly are obvious.

3. AERONAUTIC INSTRUMENTS.

J. A. C. Warner.

The aeronautic instruments section has continued its program of research and development for the Army, the Navy, and the National Advisory Committee for Aeronautics on funds furnished by these organizations and, to a more limited extent, has undertaken work for other Government departments. In addition to the development of new instruments fundamental, theoretical, and experimental researches have been conducted in connection with the theory of elasticity as related to the performance of instrument diaphragms. A large amount of routine work on instruments submitted for tests has also been carried out during the year.

In this report the work may be considered under two heads: First, the experimental investigations and researches which relate to the fundamental physical principles involved in instrument development; and second, the practical design and construction of new types of aircraft instruments.

Investigation of Bourdon Tubes (Keulegan, Beij).

This investigation has included the development of the theory of the deflection of Bourdon tubes and a study of their elastic errors. A new formula for the deflection of these tubes has been derived on the assumption that the deformation of the walls is entirely of a flexural nature, and that any lateral cross section is made up of two circular arcs of equal lengths and of the same curvature. The method followed was that of equating the work of deformation to the external work done. The new formula agrees with experiment far more closely than does any of the formulas previously developed. Hysteresis, drift, and recovery curves have been obtained for several Bourdon tubes for various ranges of loading. In connection with this experimental work a study has been made of Boltzmann's theory of time effects and the conclusions drawn therefrom have been compared with the test results wherever possible. The work done up to the present time involves (1) the determination of Boltzmann's time function from the drift curves obtained experimentally; (2) computation of recovery, the predicted results being found to agree with experiment; and (3) the separation of directional or elastic hysteresis from time hysteresis. Among the conclusions drawn from the theoretical investigation are the following: (1) For small loads the time hysteresis is approximately half of the total hysteresis, (2) aftereffect is independent of directional hysteresis, (3) drift and recovery are proportional to the maximum pressure, and (4) time hysteresis varies but slightly with changes in the rate of loading.

Investigation of Metallic Diaphragms (Keulegan, Henrickson).

The investigation of metallic diaphragms has been continued, both as regards the determination of empirical laws for the deflection of such diaphragms and as regards their elastic errors. Empirical formulas have been developed for the deflection of flat and corrugated diaphragms, both for distributed and for concentrated loads. Progress has been made in developing the mathematical treatment of the deflection of a corrugated diaphragm, using the theory of shells as given in mathematical treatises on elasticity. A study of

accurately determined hysteresis loops for flat diaphragms indicates that, when the drift is small, the maximum hysteresis occurs at a load equal to one-half the maximum load of the cycle and the hysteresis curve is symmetrical about the maximum. This was found to be true both for different materials and for different loads, providing the load was not too great. The magnitude of the hysteresis was found to be proportional to the maximum load of the cycle for similar cycles in which the rate of loading was the same. After-effect was found to be proportional to the maximum load of the cycle.

Investigation of Nonmetallic Diaphragms (Eaton, Buckingham).

Thin rubber and a large number of leathers and doped fabrics have been studied during the past year to determine their possibilities for use as nonmetallic diaphragms. Methods of predicting the load-deflection curve for a diaphragm of known slackness used in conjunction with a spring of known stiffness have been developed, thus making it possible to design in a scientific manner a slack diaphragm pressure element. Load-deflection curves computed from the theory are being compared with the corresponding curves determined experimentally. Diaphragms of various degrees of slackness have been studied under different conditions of temperature and humidity. Humidity is found to be one of the most troublesome factors affecting the performance of slack diaphragms, for changes in it alter the degree of slackness, which in turn affects the effective area and consequently the load-deflection curve. Tests have been conducted to determine the permeability of the various materials to air for a large range of pressures. The effect of humidity and the fact that some of the most promising materials were quite permeable to air led to the attempt to reduce these effects by the surface application of various dopes furnished for the purpose by the chemistry division. It was found that these dopes closed the pores of the material, rendering it less permeable and reducing the effect of humidity, but that the effect of temperature changes on the material was greatly increased. It is considered that alum-tanned colon leather is the most suitable of all the materials yet studied for use as a non-metallic diaphragm.

Investigation of Barometric Sylphon Diaphragms (Keulegan, Beij).

Two sylphon diaphragms exhausted to a low pressure and provided with internal springs were tested for the Army Air Service to determine the magnitude of their elastic errors. The hysteresis exhibited by these diaphragms was less than 0.5 per cent for a differential pressure of 54 centimeters of mercury.

Investigation of Gasoline Flow Meters (Sylvander, Frymoyer).

A report containing the results of a thorough investigation of the performance of various types of flow meters suitable for aircraft has been submitted to the Bureau of Aeronautics, Navy Department. The balanced-vane type was found to be superior to the vertical float type of instrument. Calibration curves for the flow meters when used with liquids of different densities and viscosities are included in this report. A report on an experimental model of a flow meter based on the principle of determining the rate of flow by measuring the temperature to which a constant and known supply of heat energy raises the inflowing liquid has been submitted to the engineering divi-

sion, Army Air Service. In connection with this investigation an apparatus for accurately and quickly testing flow meters has been developed.

Investigation of Aircraft Sextants (Beij).

This investigation, involving the study and testing of all the types of aircraft sextants for the purpose of finding the most suitable form for aircraft use, has been completed for the present. During the past year two types of sextant were studied. A tentative design for an improved bubble sextant, based on the results of this investigation, has been prepared.

Bimetallic Bars (Keulegan).

Bimetallic bars are used for temperature compensation in instruments, as thermometric elements, and as a means of temperature control. The theory of these bars has been developed in preliminary form. Tests on bars made of brass and invar elements indicate that the deflection of a given bar can be predicted within 10 per cent by this theory.

Theory of Rate-of-Climb Indicators (Mears, Brombacher).

Considerable work has been done in developing the theory of the leak type of rate-of-climb indicator. The work has been divided into two parts: (1) The general theory of the instruments and (2) the effect of temperature on the indications. The development of the general theory has involved the determination of the relation between the rate of climb and the construction constants and the performance characteristics of the instrument. Special attention has been given to the theory of lag, since it is exceedingly important to reduce the lag to a minimum when these instruments are used on lighter-than-air craft. The effect of temperature on the indications of rate-of-climb indicators has been studied for each of three assumptions: (a) That the indicator is at the free air temperature and the altitude is determined by pressure and temperature observations, (b) the same as (a) except that the altitude is determined by pressure observations only, and (c) that the indicator is at a constant temperature and the altitude is determined as in (a). The corrections computed for case (b) have been verified by experiment. This research was conducted in connection with the development of rate-of-climb instruments. The results, however, have not yet been prepared for distribution.

Design of Springs for Instruments (Brombacher).

(a) *Plate springs*.—A formula has been developed for the deflection of plate springs supported at both ends and subjected to a central load, the springs having varying moments of inertia. The particular formula developed is for a spring in which the moment of inertia varies in accordance with one law from the support to a point part way toward the center and in accordance with another law from this point to the center of the spring. A method has been devised, however, whereby the formula for deflection can be written by inspection when the variation of moment of inertia can be expressed for successive portions of the spring.

(b) *Helical springs*.—Work has been initiated in connection with the preparation of monograms for use in the design of helical springs. The available formulas for these springs have been studied critically

and the exact cases to which they apply determined. It is planned to conduct experimental work to verify the theoretical results and to acquire information as to the effect of factors which can not be easily included in the formulas.

Methods of Reducing Astronomical Observations in Aerial Navigation (Beij).

The use of maps in finding position from astronomical observations has been studied. This investigation, which covers the problem of methods for the reduction of astronomical observations suitable for aircraft use, has been completed.

Reports on Aerial Navigation (Beij, Warner).

A report on the navigation of aircraft by astronomical observations is nearing completion. This report includes a brief outline of the theory of astronomical position finding and its application to the navigation of aircraft, as well as a complete bibliography of the subject. Instruments for observation are described, and the problems encountered in their use are discussed. The various methods of reducing observations are described in detail and their practical value for aerial navigation compared. A report on night and cloud flying has also been nearly completed. This report includes a discussion of aerial lighthouses and beacons, field lighting equipment, and devices for aid in landing in fog. The methods of navigating aircraft at night and in clouds are reviewed, and the instruments required for this purpose are described.

Report on Aircraft Compasses (Seward).

A report has been prepared embodying the results obtained from extensive laboratory tests on 43 makes of airplane compasses representative of American, British, French, German, and Italian service and experimental instruments. This report contains a brief description of the physical characteristics of each of the compasses tested, together with curves for air and liquid damping. Curves showing the effect of temperature upon the period of the liquid damped compasses are also included. The experimental work was conducted in cooperation with the Bureau of Aeronautics, Navy Department.

Ground Speed and Drift Indicator (Sylvander).

The gear-driven ground speed and drift indicator of the optical synchronized type has been completed and delivered to the engineering division, Army Air Service. This instrument contains a specially designed 5-speed gear box to provide for the range of speeds required in the instrument. The instrument was found to function satisfactorily both in laboratory and in flight tests. The indicator as finally constructed should prove durable and simple to operate. An electromagnetic eddy current type indicator designed to eliminate the friction drive on the altitude scale has also been designed, but has not been developed fully.

Distant Indicating Tachometer (Sylvander, Frymoyer).

A distant indicating tachometer of the commutator-condenser-galvanometer type has been designed and constructed. The commutator is attached to the shaft whose speed is to be measured and alternately charges a condenser from a battery and discharges the condenser through a sensitive galvanometer, the successive dis-

charges coming with sufficient rapidity to produce a steady indication on the galvanometer. This instrument has the advantage that it can be used under circumstances where but a small amount of power is available to operate the speed measuring device.

Turn Indicators (Sylvander, Frymoyer).

The new electrically driven gyroscopic turn indicator has been completed. Laboratory and flight tests on the instrument compare favorably with those on the air-driven instruments. This instrument, however, has the advantage, especially when used on lighter-than-air craft, in that its sensitivity is the same at all speeds, while an air-driven instrument does not function satisfactorily at low air speeds. Several new instruments of this type designed during the past year by private firms have been studied in the laboratory and in flight.

Electric Turn Meter (Sylvander, Frymoyer).

A new electrically driven gyroscopic turn meter has been designed and constructed. It consists of a small, specially constructed battery motor in which the armature rotates about the field on ball bearings, thus forming the rotor of a gyroscope. The gyroscope is mounted in such a way as to allow it to precess about one axis only, the fore and aft axis, when mounted in the aircraft. The turning movement of the ship causes precession about this axis, which is indicated by a suitable mechanism. This instrument is extremely sensitive and measures quantitatively the rate at which the aircraft is turning from a given course.

Horizontal Angle Indicator (Beij, Parkhurst).

The horizontal angle indicator, which is intended to be used in range-finding work from captive balloons or dirigibles, measures simultaneously the horizontal projection of the angle between two given points and the depression angles to each of the points. This instrument has been constructed during the past year and is now practically ready for test.

Precision Barometer (Mears, F. Cordero).

As a result of flight tests on this instrument it was found desirable to change the indicating mechanism. The original indicating mechanism consisted of a shifting dial, while the new mechanism consists of a spiral scale, the pointer making three revolutions in each mechanism. To show at a glance which portion of the spiral should be read in any given instance, the instrument is provided with an auxiliary pointer rotating through a much smaller angle than does the main pointer and passing over an auxiliary scale divided into three portions. Each portion of this auxiliary scale is enameled in a characteristic color corresponding to the colors used in graduating the three portions of the spiral scale. The Air Service loaned this instrument to the Engineer Corps, and it has been used with marked success in an automobile to determine the contour of the country around Dayton, Ohio, for establishing check points in aerial mapping.

Precision Altimeter (Mears, Brombacher).

A precision altimeter was designed and constructed during the past year. This instrument is almost entirely free from the usual

elastic errors of aneroid barometers and yet is nearly as small as the ordinary service altimeter. The pointer makes two revolutions for the 10,000-foot range of the instrument. Laboratory tests are now being conducted, and slight modifications of the mechanism are being made. With minor changes in design this altimeter could be adapted to use as a precision surveying or engineering aneroid barometer. It also could be made to serve as the basis for the development of a somewhat larger model which would be suitable as a substitute for mercurial barometers for meteorological purposes.

Precision Barograph (Mears).

A combined altimeter and barograph provided with an indicating dial like an ordinary altimeter and with a recording device similar to that of the older model precision barograph described in last year's report has been designed and constructed. The present instrument is an improvement of the older model, having been considerably reduced in size and otherwise modified. However, the straight-line motion of the pen, which was the main feature of the former instrument, has been retained, thereby making possible the use of rectangular coordinates on the chart. This instrument has been given its preliminary laboratory tests and should soon be ready for flight tests.

Temperature-Compensated Altimeter with Expansion Thermal Element (Mears, F. Cordero).

The use of a bimetallic strip for temperature compensation has been found unsatisfactory because of its thermometric lag. Considerable development work has been conducted on an altimeter which is to be corrected for free air temperature by the use of an element operated by the change in volume of a liquid which completely fills an expansion chamber.

Temperature-Compensated Thermobarograph (Mears, F. Cordero).

A temperature-compensated thermobarograph has been under development during the past year. This instrument gives a record of altitude corrected for air temperature, together with a record of the air temperature itself. This problem is especially difficult, because it requires a pressure element compensated for temperature at all temperatures and pressures which may be encountered and in addition a thermal element free from any altitude effect due to pressure.

Open-Scale Landing Altimeters (Brombacher, Sutton).

Three open-scale altimeters suitable for the landing of aircraft are under construction for use on the Navy rigid dirigible *ZR-1*. They have a range of about 3,000 feet and are provided with a protective apparatus which prevents the injury of the instruments if the craft is flown at higher altitudes. It is expected that these instruments will not have an error greater than 10 to 20 feet. A very important problem in connection with these altimeters is the location of a suitable point for mounting the outlet or static head when they are used on heavier-than-air craft. The static pressure at the point where the instrument is mounted differs slightly from the static pressure of the free air at the same level owing to the flow of air around the fuselage. This effect is too small to affect the reading

of the ordinary altimeter, but might cause errors several times as great as the maximum allowable error for these sensitive instruments.

Surveying Aneroid (F. Cordero).

A surveying or engineering aneroid has been developed at this bureau and is now being given field tests by the United States Geological Survey. In designing this aneroid the object in view was to produce an instrument which would be practically free from all the elastic errors of the commercial aneroid barometer and which at the same time would be rugged enough to stand the jars and shocks to which these instruments are subjected during transportation and field use.

Mercurial Barometer Design (Brombacher).

The mercurial altitude barometer designed at this bureau in 1918 has formed the basis of the new design made during the past year. The new features include making possible the transportation and reading of the barometer in a motor truck and preventing the contamination of the mercury in the cistern. A support for mounting the instrument on the truck was designed. The design of this barometer makes use of the advantageous principle of having the cistern closed and compensating for the change of level of mercury in the cistern by contracting the scale divisions.

Mechanical Statoscope (Mears, Strother).

The automatic electrically-operated valve used in this statoscope required further development before the instrument gave satisfactory performance. This work was carried out during the past year, and the instrument was completed and delivered to the Army Air Service.

Improved Mechanical Rate-of-Climb Indicator (Mears, Strother).

This instrument is an improved model of small size for use on heavier-than-air craft. The construction is nearly complete, and the indicator should soon be ready for flight tests.

Improved Liquid Rate-of-Climb Indicator (Strother).

A liquid rate-of-climb indicator with a very open scale has been designed and is now being constructed. This instrument is of importance in weighing off and landing dirigibles, the navigating officers depending on it almost entirely for this purpose. It is expected that this instrument will be tested and put into service on the Navy rigid dirigible *ZR-1* shortly.

Combined Statoscopes and Rate-of-Climb Indicators (Mears, Parkhurst).

These instruments are intended to replace two separate instruments which are essential to the operation of aircraft, thus reducing the number of instruments carried. When used as statoscopes, they indicate small changes in altitude, while when used as rate-of-climb indicators they measure the rate of change of altitude. Two types of these combined instruments have been under construction during the past year, the first of which was described in last year's report. Considerable trouble has been experienced with this type in getting a sufficiently small delayed-action relay to operate the valve in a satisfactory manner and in obtaining a suitable multiplying mech-

anism which will operate properly both when the instrument is used as a statoscope and when it is used as a rate-of-climb indicator, using the present sylphon diaphragm element. The second type under development is similar to the first except for the electrically-operated valve. The new automatic valve (preliminary model developed by Sutton) consists of an electromagnetically operated pawl with suitable cams for actuating the equalizing valve and for shutting off the current at the proper moment. The multiplying mechanism has been greatly simplified. Three instruments of this type are under construction.

High-speed Air-speed Indicators (Henrickson).

Six Pitot type air-speed indicators reading to 250 miles per hour were provided on short notice for the Bureau of Aeronautics, U. S. Navy, for use on racing planes by remodeling a number of water-ballast indicators.

Suspended Head Electric Air-speed Indicators (Eaton, Henrickson).

Two electric air-speed indicators of the commutator-condenser-galvanometer type have been constructed for the U. S. Navy for use on rigid dirigibles. These instruments are of the suspended head type, the propeller and commutator of each being mounted in a stream-lined case and suspended about 40 feet below the ship. Considerable work was necessary to develop a stream-lined head which should be sufficiently compact and light and at the same time stable in flight. Each instrument has an extra indicator, so that the air speed can be read at two different parts of the ship simultaneously. A feature of this type of instrument is that as many indicators as desired may be connected in series to the commutator without affecting the reading which would be given by any one of them if used alone.

Gas Pressure Alarm (Henrickson, Eaton).

The need for an instrument which will give warning when the gas in one of the cells of a rigid dirigible has expanded to fill the cell and has begun to build up an excess pressure has led to the development of a gas-pressure alarm. The instrument is in the form of a large push button which is mounted on springs on a girder just below the gas cell and which is deflected by the lower wall of the cell when the pressure inside exceeds that of the external air. As the push button deflects, it completes an electrical circuit by closing contacts which are hermetically sealed in a sylphon diaphragm filled with carbon tetrachloride. A second sylphon connected with the first by means of a small tube serves as an expansion chamber, allowing the first sylphon to deflect under pressure. The closing of the electrical circuit operates simultaneously a buzzer and a red lamp in the cabin.

Ballonet Volume Indicator (Eaton, MacNair).

A ballonet volume indicator of the static pressure type has been constructed. This instrument measures the difference in pressure between the gas bag and the ballonet of the ship, and so is in reality a delicate pressure gauge, giving full-scale deflection for a head of 1 centimeter of water. A sufficiently sensitive pressure element was obtained by using a thin colon leather diaphragm with a very

flexible steel spring. The leather diaphragm was treated with a special dope which made it more nearly impermeable to hydrogen and which was affected by temperature in such a way as to compensate in part for changes of temperature of the gas and air.

Fabric Tension Meter (Eaton, Keulegan).

The necessity for knowing the tensions in the gas bags of non-rigid dirigibles and in the outer cover of rigid dirigibles has brought about the development of a special tension meter for this purpose. The instrument is attached to the outside of the fabric temporarily by means of an elliptical rim containing a large number of suction holes. This rim surrounds an elliptical inner chamber into which the fabric can be deflected a known amount by an applied suction whose magnitude is measured by means of a gauge attached to the instrument. If two such measurements are made at a given point of the fabric with the major axis of the instrument placed successively in directions at right angles to each other, the tensions in these directions can be computed. Furthermore, if four readings are taken with the major axis of the instrument placed successively in directions at 45° with one another, it is possible to compute the magnitudes and directions of the maximum and minimum stresses.

Mine Depth Recording Instrument (Mears).

This instrument was designed and constructed in cooperation with the Navy Department for use in determining the depth and small variations in depth of submarine mines. The chart of the instrument has a range of 30 feet, the instrument being adjustable so that this range may be had at any depth from 0 to 120 feet of water. The scale is sufficiently open to be read to within 1 inch of water.

Aircraft Compasses (Seward).

A magnetic compass especially adapted for use on an airplane equipped with a turn indicator was designed and constructed for the Army Air Service. The instrument was designed so as to give quick recovery of the card after a disturbance. A Navy Mark II compass has been modified to incorporate, as far as possible without complete redesign, the results of extensive laboratory and flight tests of all types of airplane compasses.

Flight-History Tests of Barographs (Sonntag).

A flight-history test is one in which the factors of time, barometric pressure, and instrument temperature are made to repeat in the laboratory the conditions of the flight. Such tests are often given the barographs carried in flights for altitude records, since by this means the most accurate determination of the altitude attained can be made. Two such altitude determinations were made by this bureau during the past year.

Sphygmomanometer Testing (Eaton, Buckingham).

The sphygmomanometer testing has grown in volume during the past year. The bureau has taken an active part in furnishing information relative to the performance characteristics of these instruments to manufacturers, to private individuals, and to Government bureaus which were contemplating the purchase of sphygmomanometers. There is a distinct field of activity for the Bureau of

Standards in connection with the standardization of blood-pressure apparatus because of the growing use and importance of these instruments in medical science.

Routine Testing.

The routine testing of aeronautic and various other closely related instruments has occupied a portion of the time of the section during the past year. The instruments tested include 14 air-speed indicators, 21 altimeters, 3 aneroid barometers, 4 surveying aneroids, 16 barographs, 3 mercurial barometers, 18 tachometers, 3 turn indicators, 2 aerial sextants, and 16 sphygmomanometers.

Flight Tests on Aeronautic Instruments.

About 30 flight tests were made during the year by members of the section in connection with the development and investigation of a number of different aeronautic instruments. The various types of aircraft necessary for these tests were furnished through the courtesy of the Army, the Navy, and the National Advisory Committee for Aeronautics.

4. AERODYNAMICAL PHYSICS.

H. L. Dryden.

The work in aerodynamics is carried on largely with the cooperation and financial assistance of the engineering division of the Air Service, United States Army, the Ordnance Department of the Army, and the National Advisory Committee for Aeronautics.

The equipment available has been described in detail in the annual report of the bureau for the year 1921-22. It comprises three wind tunnels, one 3 feet in diameter, with a speed range of 11 to 180 miles per hour; one $4\frac{1}{2}$ feet in diameter, with a speed range of 17 to 90 miles per hour; and one 10 feet in diameter, with a speed range of 15 to 70 miles per hour. Apparatus is available for all types of aerodynamic testing except propellers.

Researches on Airship Models (Upton, Frisby, Hill, Boyd, Temin).

An extensive program relating to the forces and moments acting on airship models, distribution of pressure over airship hulls, and damping coefficients for airship models has been carried on through the year for the engineering division of the Air Service. The results are incorporated in a series of nine confidential reports forwarded to the engineering division. The major part of the work has been done in connection with the design and construction of the *RS-1* semirigid airship.

A knowledge of the distribution of pressure is very essential for the computation of stresses in the fabric and in the keel girder, as well as for the proper reinforcement of areas subject to large inward pressures. Measurements have been carried out on the hulls of the military airship (an existing type) and on the hull of the *RS-1* with the hull at various angles to the air stream. Methods have been developed for the graphical integration of the local pressures to give the component forces on any section of the envelope.

The presence of the control surfaces modifies the distribution of pressure over the envelope to a very marked degree, and this effect

is now being studied. This will be followed by an investigation of the distribution of pressure over the controls.

A study of the total forces and moments acting is very necessary for estimates of performance and stability. Such studies have been made of the military airship, the type A. P. high altitude observation balloon, and of the *RS-1* under many conditions. Comparative tests were made on four Goodyear models prior to the selection of the hull for the *RS-1*. The selected hull was then tested with 12 sets of fins with control surfaces neutral. On the basis of these tests two sets of fins were selected for further tests with controls at angles and for oscillation measurements.

Incidental to the main program measurements at several wind speeds were made to determine the magnitude of scale effect to be expected. Most of the tests described were of a comparative nature, but for final predictions the scale effect must be known. Some work was also done in connection with improvement of the methods of measurement.

Researches on Aircraft Bombs (Dryden, Heald).

Researches on models of aircraft bombs have been carried on in cooperation with the Ordnance Department of the Army.

The work on the measurement of damping coefficients has been continued. Some work has been done on the mathematical theory of the motion with center of gravity fixed and restoring force due to the air motion alone. It is proposed to carry out some experimental work along this line.

A study has been made of a model of a bomb designed by Dr. E. J. Loring, of the Ordnance Department, to provide data for the selection of the proper amount of fin surface to secure satisfactory stability.

A comparison has been made of tests of a 4-inch model in the 54-inch tunnel with tests of the full-scale bomb in the 10-foot tunnel with very satisfactory agreement both as regards forces and moments.

The problem at present engaging attention is the development of a satisfactory method for estimating fin surface sufficient for stability. At present an empirical rule is used and tests are now under way to determine its validity. The tests involve a series of determinations of center of pressure positions for various models.

Researches on Roof Ventilators (Dryden, Heald).

The preliminary report on tests of roof ventilators created such interest that the apparatus was again assembled and the tests extended to samples submitted by other manufacturers. These ventilators are used in connection with natural systems of ventilation for factories, school buildings, etc. The principles involved are few in number, although the number of different samples in production is very large. The bureau's investigations cover the principles involved in producing an exhaust by means of a wind normal to the axis of the ventilator. The results have led to a few simple designs, some of which have been adopted by manufacturers desiring to improve their product.

A few tests have been made approximating conditions on a peaked roof, and other tests have been made on two of the ventilators on an installation characterized by a very low resistance to flow.

Studies of Wind Tunnel Air Streams (Dryden, Heald).

The study of the air stream of the 3-foot tunnel, including the determination of its speed by an absolute method, has been continued under a grant from the National Advisory Committee for Aeronautics. The very great importance of eliminating long connections to the measuring instruments has been shown by various tests. The principal contribution to the bureau's knowledge of the character of the speed fluctuations lies in the discovery that the period of the disturbances is independent of the wind speed, and that the approximately constant period is characteristic of stationary waves in the tunnel. No way has yet been found of eliminating these high-frequency fluctuations. The phase relations of the pressure wave and the velocity wave show the importance of eliminating the effect of the pressure wave in studying velocity fluctuations.

Numerous additional observations have been taken of the speed of balloons allowed to float along the tunnel. The speed of the balloons, as determined by the mean of 40 observations, is equal to the speed as given by the Pitot tube within one-fourth of 1 per cent, but the deviations of individual observations are quite large. Various methods have been tried to reduce the deviation, without success, the deviations being due, apparently, to the erratic motion of the balloons.

Resistance Measurements in a High-speed Air Stream (Hull, Briggs).

Resistance measurements of models of projectiles and bombs have been continued during the year for the Ordnance Department, using a high-speed air stream supplied by large centrifugal compressors at the Lynn works of the General Electric Co. The head resistance of bomb models has been measured through the entire speed range of an aircraft bomb falling from a height of 16,000 feet. Resistance measurements of model projectiles have been extended to speeds of 1,560 feet per second, using a divergent orifice approximately 8 inches in diameter and a gauge pressure on the orifice of about 28 pounds per square inch. In these measurements the stationary compressional wave in front of the projectile could be clearly seen as a well-defined shimmering surface.

SPECIAL INVESTIGATIONS.

Theory of Dimensions (Buckingham).

Dimensional theory is of prime importance in technical physics, because many problems which are too complicated to be handled at all by ordinary theoretical methods can be successfully attacked by an experimenter who is guided by the theory of dimensions.

A great deal of research, particularly in hydro and aero dynamics, is now conducted by means of models, the experiments being planned and the results translated into information about full-scale performance by means of dimensional theory.

A member of the section has continued to give a part of his time to the development of this subject, upon which an increasing amount of correspondence is being carried on with engineers in addition to consultations with members of the Navy Department on some of

their problems of design. Six lectures were also delivered on the theory and interpretation of model experiments before military and civilian members of the Navy Department.

Earth-Inductor Compass (Heyl, Briggs).

A new type of airplane compass was developed last year for the Air Service, in which the orientation of a craft is determined by balancing components of the electromotive forces set up in coils spinning continuously in the earth's magnetic field. The same principle has since been applied in the construction of a compass suitable for ocean-going vessels, and a sea test will shortly be made. This type of compass may be located in that part of the vessel which is least magnetically disturbed, and its indications electrically transmitted to the bridge.

Gravitation and the Einstein Theory (Heyl).

The increasing importance of Einstein's theory of gravitation has led the bureau to subject the fundamental postulate of this theory to experimental examination from a new direction. This postulate, called the "Principle of equivalence," asserts in effect that gravitation and inertia are indistinguishable because identical in their nature. The physical basis for this assumption is the fact that the inert mass of a body is known to be proportional to its gravitative mass to a high degree of precision (about 1 part in 20,000,000); in other words, the intensity of gravitation is independent to this degree of the material experimented upon. One line of investigation of this point has had but very little experimental attention—the possibility that a crystal may show different gravitational properties in different axial positions. This line of experiment has been carried out rather completely, covering all the nonisometric systems of crystals, and reaching the record precision of 1 part in 1,000,000,000 (10^9). The work is about four-fifths completed, and to this high degree of precision no gravitational difference has been discovered. The experiments have failed to prove Einstein wrong. They can not, of course, prove him right. Incidentally, this work has led to a practical method of comparing weights with a precision of 1 part in 1,000,000,000. The best previous record of this kind is that of the comparison of standard kilogram at the International Bureau, where the precision (as an average of a series) has reached about 7 parts in 1,000,000,000.

Orifice Meters (E. Buckingham, Bean).

Orifice meters, though comparatively modern instruments, are already widely employed in the industries. One of their most important uses is in the measurement of natural gas, and the Government receives large royalties based on such measurements. It is consequently desirable that orifice meters be standardized authoritatively, and that satisfactory testing methods be developed.

While a good deal of private experimental work has been done on orifice meters, numerous questions regarding their behavior and accuracy under various working conditions need further study, and repeated requests for information led to the initiation of the present research. Its purposes are: To analyze all the available data so as to get as much from them as possible; to get reliable first-hand experi-

mental information on certain doubtful points, and ultimately to devise practical methods for testing commercial orifice meters.

One of the questions concerns the behavior of orifices at the high gas pressures used in natural gas lines, all previous work having been done at low pressures. As this point seemed of particular interest to natural gas engineers, advantage was taken of an offer of cooperation by the Chemical Warfare Service, who are loaning to the bureau the use of a large compressor plant at Edgewood Arsenal.

The primary purpose of the work at Edgewood is to standardize, at various pressures up to 300 pounds per square inch, a number of orifice plates which can later be tested also at low pressures, so that the effects of changes of pressure may be accurately known. When this has been accomplished, further standardization work can be carried out without the difficulty and expense attendant on the use of high pressures.

The facilities at Edgewood for producing high-speed air jets will permit of certain highly desirable experiments on that very important instrument, the impact tube; and it is hoped that this problem may also be taken up.

Hardware Standardization (Fairchild).

The purpose of this work is to standardize builders' hardware for Government as well as private use; to carry out such laboratory tests as may be necessary to insure the adoption of articles having the requisite characteristics regarding durability and performance; to make such surveys as may be required to insure the adoption as standard of those items found in general commercial production. The Advisory Committee on the Standardization of Builders' Hardware, consisting of representatives of the prominent manufacturers in this field, has organized separate subcommittees on locks, butts, and shelf and miscellaneous hardware, which have held frequent meetings among the manufacturers of these lines. In the case of several companies, the recommended standards have been set up at the factories almost immediately following the committee meetings, with the general understanding that the standards will be adopted by all companies as early as they find it practicable. The standard items of builders' hardware recommended by the manufacturers are being incorporated into the Government specification for builders' hardware which is nearing completion under the administration of the builders' hardware committee of the Federal Specifications Board.

Following a conference of the Hollow Metal Door Manufacturers with the representatives of hardware manufacturers, the architects, and the Government, a number of items of builders' hardware have been recommended as standard for hollow metal doors, and an arrangement of holes in templet butts, together with rules for butt sizes on hollow metal doors, have been formulated preparatory to recommendation as standard.

A report on the relative wearing value of ball-bearing and steel-bushed bronze butts as shown by an accelerated service test carried on at the Bureau of Standards, indicating the relative merits of various types, has been issued to the manufacturers and the results also published in *Hardware Age*.

Plumbing Investigations (Hunter).

The plumbing investigation undertaken in November, 1921, for the housing division of the bureau for the purpose of obtaining and correlating data on which to base rules of construction for simple, economical, and efficient plumbing in small dwelling houses was continued through the past year and has been completed for dwelling-house plumbing.

The work has involved: A study of water and air movements in plumbing systems with numerous experiments on stack and vent systems, including several complete test plumbing installations; a study of the characteristics of sewage discharge through stack and horizontal drain systems with a view to the proper proportioning of sizes of soil and waste stacks, vents, house drains, etc., to the number of fixtures on the system; a study of trap siphonage and the means of preventing it by a proper design of the system; the preparation of charts and tables for the practical application of the results obtained; the preparation of a report of the investigations; and, in connection with the subcommittee on plumbing, the formulation of a recommended plumbing code, based on recognized good practice and the results of the bureau's investigations.

Further experiments have been made to determine the serviceability of a 3-inch soil stack for larger plumbing systems. The report of the investigations and the recommended plumbing code are ready for publication in the final report of the subcommittee on plumbing.

PUBLICATIONS.

The following papers have been published during the year:

- High pressure steam-heating lines (E. Buckingham), *Mechanical Engineering*, October, 1922.
- Rate of exhaustion of a closed tank by a reciprocating air pump (E. Buckingham), *B. S. Tech. Paper*, No. 224, January 4, 1923.
- Jet propulsion for airplanes (E. Buckingham), *N. A. C. A. Report* No. 159; 1923.
- Leakage through thin clearance spaces (E. Buckingham), *Engineering*, February 23, 1923.
- Tests of radiator traps (W. F. Stutz), *Jour. Am. Soc. Heating and Ventilating Eng.*, March, 1923.
- Testing of anemometers (O. J. Hodge), *Jour. Am. Soc. Heating and Ventilating Eng.*, March, 1923.
- The acoustics of rooms (E. A. Eckhardt), *Jour. Franklin Institute*, June, 1923.
- A method for the measurement of sound intensity (J. C. Karcher), *Sci. Paper*, No. 473 (part of vol. 19), May 7, 1923.
- A Piezo-electric method for the instantaneous measurement of high pressures (J. C. Karcher); *Sci. Paper* No. 445 (part of vol. 18), August 4, 1922.
- An electron-tube tuning fork drive (E. A. Eckhardt, J. C. Karcher, and M. Keiser), *Jour. Optical Soc. of America and Review of Scientific Instruments*, Vol. VI, No. 9, November, 1922.
- Altitude effect on air-speed indicators II (H. N. Eaton and W. A. MacNair), *N. A. C. A. Tech. Rept.* No. 156.
- Aeronautic instruments (F. L. Hunt), *Jour. Opt. Soc.* Vol. VI, No. 7, September, 1922, *B. S. Tech. Paper* No. 237.
- Diaphragm investigation, Pt. I (M. D. Hersey), *N. A. C. A. Tech. Rept.* No. 165.
- Optical night altitude indicator (J. A. C. Warner), *Jour. Opt. Soc.*, vol. 7, No. 3, March, 1923, *Aviation*, Vol. XIV, No. 11, March 12, 1923, *N. A. C. A. Tech. Note* No. 123.
- The determination of the altitude of aircraft (W. G. Brombacher), *Jour. Opt. Soc.* (in press).
- The relative wearing value of ball-bearing and steel-bushed bronze butts (I. J. Fairchild), *Hardware Age*, March 31, 1923.

STRUCTURAL, ENGINEERING, AND MISCELLANEOUS MATERIALS.

P. H. Bates.

FUNCTIONS.

This division is concerned with the investigation of the properties, uses, design, and fabrication of structural, engineering, and miscellaneous materials. This includes metal of all kinds, and wood, especially when fabricated into structures or structural parts, cement, concrete, lime, gypsum, sand, stone, and sand-lime brick. Under miscellaneous materials are included leather, rubber, and composition materials used in place of these, textiles, and paper. To make the study of these products complete, it is desirable to take into consideration the processes by which they are manufactured. Hence, the equipment includes an experimental rubber mill, textile mill, paper machine, cement plant, etc. The division is also concerned in the improvement of the present and the development of new methods of testing and the establishment of standards covering the manufacture and the use of the materials concerned.

SECTIONS.

1. Structural and engineering materials.
2. Cement, concrete, and stone.
3. Leather and rubber.
4. Textiles.
5. Paper.
6. -----
7. Lime, gypsum, and sand-lime brick.

GENERAL STATISTICS.

Staff	96
Expenditures (1922-23)	\$223, 000
Tests completed	16, 425
Researches completed	30
Bureau publications	8
Other technical publications	39

WORK CHART.

I. STRUCTURAL AND ENGINEERING MATERIALS.

SCOPE.

Measurements of the resistance of fabricated structural units under tensile, compressive, and torsional stresses.

The study of testing apparatus and testing methods.

The determination of physical properties of new material.

The design and testing of structures.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Steel.....	293	467
Iron.....	119	22
Other metals and alloys.....	472	578
Enamels for sheet metals.....	87	
Rope:		
Wire.....	29	8
Manila.....	54	46
Sisal.....	4	4
Calibration of testing machines.....	8	2
Large H columns.....	4	13
Structural members (Delaware River Bridge).....	6	
Miscellaneous.....	221	164

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Laboratory tests and field trials with recording extensometer.....		80	
Physical properties of materials.....		100	C101.
Strain gauge measurements on engineering structures:			
Optical strain gauge.....	Navy Department.	100	Outside. ¹
Arlington Building.....	Treasury Department.	100	T236.
Calibration of testing machines.....		10	
Strength of steel columns.....		50	
Fatigue properties of woods and metals.....		10	
Specification for wire rope.....	Federal Specifications Board.	90	
Tanks.....	American Bureau of Welding.	100	
Brinell testing.....		25	
Brickwork:			
Ideal walls.....	Common Brick Mfrs. Assn. and Sand-Lime Brick Assn.	60	
Hollow tile.....	National Fireproofing Co. and A. S. T. M.	100	
Delaware River Bridge tests.....	Joint commission of Pennsylvania and New Jersey.	90	
Comparison of Humphrey and Izod machines.....		80	
Steel columns.....	American Bridge Co.; Bethlehem Steel Co.	80	
Fatigue of duralumin.....	Navy.....	60	
Building stresses.....		50	
Allowable loads on corrugated zinc roofing.....	American Zinc Institute.	10	
Girder hooks.....	American Bridge Co.	70	

¹ Proc. A. S. T. M.; 1923.

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Welded rail joints.....	American Elec. Ry. Assn.; American Bureau of Welding; National Research Council.	5	
Crinkling stresses.....	Navy.....	35	
Riveted joints.....	do.....	5	
Bibliography on riveted joints.....		100	

2. CEMENT, CONCRETE, AND STONE.

SCOPE.

Inspection and testing of cement for Government departments.

Researches in cement, concrete, and building stones.

Development of specifications and methods of tests for these materials.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Cement.....	3,900	5,200
Concrete.....	1,000	811
Aggregates.....	25	58
Concrete products.....	11	42
Testing sieves.....	37	124
Miscellaneous.....	180	372
Building stones.....	30	106

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Portland cement stucco.....		75	Outside. ¹
Reinforced concrete.....		Continuing.	Outside. ² T 220, T 223. T 214.
Durability of concrete in alkali soils.....		80	
Properties of building stones.....		Continuing.	
Properties of Indiana limestone.....		25	
Volume changes in concrete.....		25	
Standard of fineness.....		50	
General concrete investigations.....		Continuing.	Outside. ³
Workability of concrete mixtures.....		35	Do. ⁴
Caustic magnesia.....		90	C135. Outside. ⁵
Constitution of Portland cement.....		50	

¹ Proc. Am. Concrete Inst., vol. 14, 1918; vol. 16; 1920.

² Proc. Am. Concrete Inst., vols. 15, 16, and 17; and Concrete, vol. 21, p. 145, November, 1922.

³ Engineering News Record, May 27, 1920; Concrete, June, 1920; Engineering and Contracting, June 2, 1920; Canadian Engineers, June 10, 1920; Concrete Products, June, 1920; Proc. A. S. T. M., vol. 20; 1920, vol. 21; 1921; Concrete, December, 1920; June, 1921; Proc. Am. Concrete Institute, vol. 19, 1923.

⁴ Proc. A. S. T. M., 1923.

⁵ Jour. Am. Ceramic Soc., July, 1921.

3. LEATHER AND RUBBER.

SCOPE.

Standards of quality, practice, and performance: (a) Apparatus, (b) properties of materials, (c) standard test methods, (d) specifications and standardization, (e) routine testing.

Industrial process investigations: (a) Experimental rubber mill, (b) experimental tannery.

Related materials: (a) Rubber compounding, (b) tanning and filling, (c) substitutes.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Leather.....	82	191
Rubber.....	776	736

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Sole leather:			
Commercial abrasion test for.....		10	
Water penetration of.....		20	
Specification for vegetable.....		50	
Chemical uniformity.....		10	
Chrome, durability.....		80	
Leather belting:			
Properties of.....		50	
Specification.....	Federal Specifications Board.	100	Outside. ¹
Upholstery leather:			
Properties of.....		50	
Specification.....		10	
Lace leather:			
Specification.....		90	
Chemical methods.....		40	
Shark leather, properties of.....		90	
Synthetic tanning materials: Tanning properties.....		25	
Substitutes:			
Artificial upholstery.....		40	
Auto-top materials.....		10	
Composition soles.....		90	
Rubber heels.....		40	
Leather from hogskins:			
Tanning tests.....		75	
Properties of.....		75	
Polishing leather for eutlery.....		40	
Rubber compounds:			
Abrasion test for.....		10	
Accelerated aging test for.....		50	
Cable investigation.....		20	
Pneumatic tires:			
Power losses in.....		50	T213.
Endurance test for.....		40	
Specification for.....	Federal Specifications Board.	50	Outside. ²
Test data on.....		100	
Specifications for:			
Cushion tires.....		10	
Inner tubes.....	Federal Specifications Board.	75	Do. ³
Test data on inner tubes.....		100	
Specially prepared rubbers.....		50	
Jar rings.....	Federal Specifications Board.	100	Do. ⁴
Teat-cup rubbers.....		100	
Packings.....		75	
Fire hose.....	Federal Specifications Board.	100	Do. ⁵
Rubber tubing.....	do.	100	Do. ⁶
Hose (various uses).....	do.	75	Do. ⁷
Drug sundries.....	do.	50	
Rubber bands.....	do.	50	
Insulating tape.....	do.	50	
General specifications for rubber goods (test methods).....	do.	100	Do. ⁸

¹ Federal Specifications Board specification No. 37.² Federal Specifications Board specification No. 3.³ Federal Specifications Board specification No. 3.⁴ Federal Specifications Board specification No. 51.⁵ Federal Specifications Board specification No. 38.⁶ Federal Specifications Board specification No. 39.⁷ Federal Specifications Board specifications Nos. 40-50, inclusive.⁸ Federal Specifications Board specification No. 59.

4. TEXTILES.

SCOPE.

Study of raw fibers: (a) Preparation, (b) grading, (c) sampling.

Study of manufacturing processes: (a) Effect of processes on finished product, (b) economics of varieties and design, (c) conditions, (d) tolerances.

Study of uses: (a) Efficient application in present uses, (b) new uses.

Methods of testing, development of, and application: (a) Chemical, (b) physical, (c) microscopic.

Handling of finished product: (a) Laundering, (b) pressing, (c) storing, (d) cleaning.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Samples tested.....	5,335	5,776

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Heat-retaining properties of blankets and clothing materials.....		80	
Abrasive qualities of fabrics.....		25	
Stress-strain relations of airship covering.....	Navy Department.	100	
Efficiency of preservatives for textiles used in fisheries.		50	
Specifications for:			
Brattice cloth.....		10	
Numbered duck.....	Cotton Duck Association.	100	C136.
Dredging sleeve duck.....		75	
Army and light-weight duck.....		50	
Shelter-tent duck.....		20	
Denim.....		40	
Felts.....		30	
Measurement of hosiery.....		50	
Blankets.....		90	
Bunting, wool.....		50	
Bunting, cotton.....		50	
Sheetings.....		30	
Conveyor belts for Post Office Department use.	Post Office Department.	50	
Investigation of substitutes for jute sandbags.....		20	
Standardization:			
Breaking strength of electrical yarn.....		50	
Endurance test of mail bags.....	Post Office Department.	40	
Methods of testing fastness of color.....		30	
Test methods for oil and moisture in press cloths.		100	T231.

5. PAPER.

SCOPE.

Physical testing: (a) Study of new devices, (b) standardization of methods, (c) development of new methods.

Chemical testing: (a) Standardization of methods, (b) development of new methods.

Microscopy and photomicrography: (a) Development of stains, (b) development of technique.

Paper mill: (a) Study of special raw materials, (b) manufacture of special papers, (c) study of processes of manufacture.

Standard specifications.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Samples tested.....	3,604	1,636

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Antitarnish paper.....		50	
Thickness testing of paper.....		100	T226.
Sizing quality.....		80	
Standard substance basis.....		100	Outside. ¹
Waterproof test.....		75	
Technical standardization.....		100	Do. ²
Simplification of sizes.....		100	Do. ³
Photomicrography of paper fibers.....		100	T217.
Rubber latex in paper.....		100	Outside. ⁴
Aging of rubber latex paper.....		100	Do. ⁵
Colored micrographs.....		25	
Classification and definitions.....		100	Do. ⁶
Foreign and domestic clays.....		75	
Case-lining paper.....		75	
Breaking and bursting test.....		100	Do. ⁷
Tensile strength test.....		100	Do. ⁸
Brittleness test.....		100	Do. ⁹
Effect of humidity on paper.....		100	Do. ⁹
Condenser paper.....		100	Do. ¹⁰
Coating paper with glue.....	National Association Glue Manufacturers.	10	
Flax straw.....		95	

¹ Paper Trade Journal, Aug. 17, 1922.² Paper Trade Journal, Dec. 28, 1922.³ Paper Trade Journal, Nov. 9, 1922.⁴ Paper Trade Journal, Dec. 28, 1922.⁵ India Rubber World, June 1, 1923.⁶ Paper Trade Journal, May 31, 1923.⁷ Paper Trade Journal, Mar. 29, 1923.⁸ Paper Trade Journal, Mar. 22, 1923.⁹ Paper Trade Journal, Apr. 12, 1923.¹⁰ Paper Industry, May, 1923.

7. LIME, GYPSUM, AND SAND-LIME BRICK.

SCOPE.

Standards of quality.
Improvement of manufacture.
Improvement of use.

Improvement of new products.
Development of new uses.
Bureau work outside of section.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Lime.....	70	34
Gypsum.....	18	12
Sand-lime brick.....	12	10

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Use of hydrated lime in Portland cement mortar.....		90	Outside. ¹
Improvement of plasticity of hydrated lime.....		50	Do. ²
Effect of addition of hydrated lime on the properties of concrete.....		50	Do. ³
Use of lime in chemical industries.....		50	C118; C143, C144.
Strength of bond between mortar and sand-lime brick.....		25	Outside. ⁴
Cause of unsoundness of lime plasters.....	National Lime Association, Contracting Plasterers' Association, International Plasterers' Union.	100	Do. ⁵
Investigation of the physical properties of calcined gypsum and gypsum products.....		95	Do. ⁶
Acoustics of wall plaster.....		50	
Effect of moisture on set gypsum plaster.....		30	
Grading of sand for sand-lime brick.....		90	Do. ⁷
Utilization of old plaster molds.....		50	
Improvement of gypsum block.....		75	
Adhesion of gypsum plaster to concrete.....	Gypsum Industries.	100	Do. ⁸
How to make lime set quickly.....	National Lime Association.	50	Do. ⁹

¹ Trans. Nat. Lime Mfrs. Assn.; 1913, 1914; Proc. A. S. T. M.; 1917; Jour. Am. Ceramic Soc.; 1919; Nat. Lime Assn.; 1917.

² U. S. patent 1410087.

³ A. S. T. M.; 1922; Rock Products, Nov. 18, 1922; Nat. Lime Assn. Proc.; 1922.

⁴ Sand-Lime Brick Association, Trans.; 1920.

⁵ Jour. Am. Ceramic Soc., Nov., 1920.

⁶ Jour. Am. Ceramic Soc., Dec., 1920; Jour. Am. Ceramic Soc., 1921; Chem. and Met. Eng., June 15, 1921; Proc. A. S. T. M.; 1922.

⁷ Trans. Sand-Lime Brick Assn.; 1918, 1921.

⁸ Proc. A. S. T. M.; 1923.

⁹ Trans. Nat. Lime Assn.; 1923.

Detailed Report of the Year's Work.

I. STRUCTURAL AND ENGINEERING MATERIALS.

H. L. Whittemore.

Telemeters (Johnston, Peters).

A set of 12 telemeters, designed in the electrical division, has been put to practical use in connection with a series of tests of duralumin girders for Fleet Airship No. 1, Bureau of Aeronautics, U. S. Navy, and on tests of 14 special column sections submitted by the Delaware River Bridge Joint Commission. These instruments were originally designed for use on the special triangular girders of Fleet Airship No. 1 and have a total range of action of 0.012 inch, in either tension or compression.

They have been used consistently to measure total deformations of twice their designed range and have shown no loss of calibration. Throughout the investigation frequent calibration checks were made to determine the constancy of the instruments' reading under continued laboratory use. As a result of this checking calibration it is believed that the original accuracy of the instruments is maintained, and it is felt certain that in ordinary use they will show accuracy

within 2 per cent. Greater accuracy can be obtained by very careful use and adjustment.

Physical Properties of Materials (Petrenko).

Circular 101, the first edition of which was published in 1921, has been revised and is now in the hands of the editorial committee. The circular contains the values for tensile, compressive, and shearing strengths, ductility, modulus of elasticity, and other related properties of pure metals, their alloys, and of wood. In addition to these, the properties of metals at elevated temperatures, their resistance to fatigue and impact, and the effect of heat treatment and cold working are given. The properties and the uses of the less commonly used metals are described briefly. Graphical representation is used in many cases to show the change of the properties of a material with changing conditions.

References to the sources are given for all values in this circular.

Optical Strain Gauge (Tuckerman).

A new optical lever system has been devised, consisting of a triple or quadruple mirror system combined with an autocollimator. The system is conveniently portable and very free from accidental disturbances. In its present construction it is sensitive to changes of approximately two hundred-thousandths of a radian, or 12 seconds of arc. With costlier lens systems it should be possible to increase this sensibility considerably, perhaps four or five times.

Used in a strain gauge with a 0.2 inch Martens lozenge, it has given consistent readings sensitive to two-millionths of an inch of deformation. This sensibility can be considerably increased, but no experiments have as yet been made to see how far this increase can be carried without undue interference from unavoidable mechanical disturbances.

This optical-lever system has wide possibilities of application to many fields of measurement, where convenience and reliability combined with high sensibility are needed. Applications to strain gauges, extensometers, torsion dynamometers, and wind-tunnel dynamometers are at present being worked out.

The present instruments were made by the Naval Gun Factory for an investigation of riveted joints for the Bureau of Construction and Repair of the United States Navy.

Test of Reinforced Concrete Floor of the Arlington Building (Larson, Petrenko).

Hollow tile and reinforced concrete floor panels, supported on reinforced concrete beams, were loaded, some to 3.8 times the design live load. The loading was designed to produce the maximum positive and the maximum negative moments. Strain measurements were taken on the concrete and the reinforcing steel of the slabs and of the girders. The deflections of the slab were measured also. In the slabs, the maximum stresses were developed at the positions of negative moment. The beams at the edges of the panels offered so little resistance to torsion that the stresses in the steel across these beams due to negative moment were little affected by a transfer of load between adjacent panels.

The effect of time under load was very pronounced in the first 20 hours, and comparatively small later. The increase in the deformation due to continued loading was greater in the reinforcement than in the concrete. The cracking of the concrete and the resulting great increase of the stresses in the reinforcing steel showed that at first the concrete carried a considerable portion of the tensile stresses.

Due to the low stresses, the moment coefficients were generally small. They are not proposed for use in design, but to show the relative amount of the bending moment carried in the two directions. The effect on the moment coefficients of an increase in the ratio of length to width of the panel was a rapid increase of both the positive and the negative moments in the direction of the short span, and a less rapid decrease of both moments in the direction of the long span.

The factor of safety of the structure was apparently greater than 2.13.

Federal Specifications Board's Specifications for Wire Rope (Whittemore).

This specification, now practically complete, has been prepared with the effective cooperation of the representatives of other Government departments and of the manufacturers of wire rope.

Using the Navy specifications for a basis, a number of changes have been made both in the form and substance. The values for the strength and other properties have been carefully checked and corrections made where necessary. Requirements for the lay of the rope have been included, as well as tests for the zinc coating.

Fatigue of Woods and Metals (Tuckerman).

Most of the work during the past year on the fatigue of metals has been on sheet duralumin for the Bureau of Aeronautics, Navy Department.

Rotary beam fatigue machines have, however, been used to test the fatigue resistance of specimens of heat treated nickel steel for the metallurgical division. It was impossible to test these specimens to failure under repeated stresses, as there are only three specimens of each heat treatment. The Smith-Gough deflection method of testing was, therefore, used successfully. The loads were increased by small increments and the deflection of the specimen measured. The stress causing a marked increase in the deflection is the endurance limit of the material.

Erratic deflection readings, obtained when this method was first used, made it seem desirable to measure the errors in loading caused by the ball bearing in which the specimen was rotated. Self-aligning bearings, having two rows of balls, which have been used in many fatigue machines of this type, particularly the machine designed by F. M. Farmer, showed that the moment on the specimen often varied 4 per cent from the computed moment.

Bearings having a single row of balls, which were mounted in trunnions, showed no variations greater than one-tenth of 1 per cent. As the self-aligning bearings had been used for this work, they were replaced by the single-row bearings and satisfactory results were obtained.

Hydrostatic and Strain Gauge Measurements on Welded and Riveted Tanks (Stang, Greene).

For the purpose of ascertaining the relative merits of riveted, as compared with electric-welded tanks, four steel tanks, 4 feet in diameter and 10 feet long, made of five-sixteenths inch mild steel plates, were tested under hydrostatic pressure. Two of the tanks were butt welded, and one was lap welded, and the fourth was of the ordinary lap-riveted construction. The ends of the tanks were spherical, having a radius of 4 feet. Strain gauge measurements were made at different pressures and the stress distribution and stress-pressure relationship obtained. The results of the hydrostatic tests proved rather unsatisfactory for comparing the relative strengths of the different types because of secondary failures.

For thin tanks, the measured stresses, based upon the dimensional formula for longitudinal as well as transverse stress in the tanks, are in close agreement with the design stresses computed by the common pressure formulas, provided the former are not affected by secondary causes. Secondary stresses, which resulted in high stress intensity and produced failure in each case, were caused by (a) faulty design of the attachment of the spherical end to the cylindrical shell, (b) nonconformity of the shell to an accurate circular section, and (c) discontinuities in the shell for the manhole and fittings.

Ideal Walls (Whittemore, Stang).

The tests of the brick walls made in cooperation with the Common Brick Manufacturers' Association have been completed, and the report prepared for publication. Doctor Stang, at the request of the association, attended the annual convention in Cleveland, Ohio, and gave them the results of the investigation. At the request of the association publication of this report was postponed, pending the completion of tests on the entire series of walls.

Delaware River Bridge Joint Commission Tests (Johnston).

In connection with the design of the new suspension bridge spanning the Delaware River from Philadelphia to Camden the joint commission of consulting engineers submitted for test 14 special I-section plate and angle columns of a so-called silicon-manganese steel. In this test the over-all dimension and construction of all columns were identical, with the exception that the web thickness was changed. The web thickness varied from three-eighths inch plate to $1\frac{1}{2}$ inches. Up to three-fourths inch in thickness they were single webs. The 1-inch thickness consisted of a series of two single webs and two one-half inch web plates stitch riveted together. The $1\frac{1}{2}$ -inch web was composed of two three-fourths inch plates stitch riveted. The principal object of the investigation was to determine the relative compressive strength of web plates, with particular reference to the ordinarily accepted design rule, limiting the minimum thickness of plate permissible.

The investigation gave further information relative to the failure of a stiffened column section and the comparative action of single and double webs. In all tests the column section used to test the compressive section of the web plate was stiffened laterally by special channel stiffeners applied to simulate the supporting conditions found in the actual tower construction of the bridge.

Comparative Tests of Notched Specimens in Izod Impact and Humfrey Slow Bending Machines (Petrenko).

The purpose of these tests was to find out the difference in behavior of various metals subjected to impact and to slow bending. The materials investigated included duralumin, brass, nickel-silver, Monel metal, 0.25 per cent carbon steel (boiler plate), $3\frac{1}{2}$ per cent nickel steel, carbon-tool steel, and high-speed steel.

These materials were tested as received from the mill without further heat treatment. The specimens were all of standard Izod type and the notches were cut perpendicularly to the direction of rolling. The results obtained indicate that in most cases there is no essential difference in the behavior of materials under impact or in slow bending, although the numerical values may be very different (Izod values are generally higher than in slow bending). In some cases the slow-bending test may be preferable, as in the former a diagram is automatically drawn, showing the relation between the angle of bending and the bending moment, which may be of value in judging the behavior of material during the test.

Strength of Large Columns of H Shaped Cross Sections (Tuckerman).

Thirty additional columns were tested during the past year. These were supplied by the Bethlehem Steel Co. The results have not been analyzed completely, but apparently they confirm the conclusions drawn from the previous tests, that the strength of the column depends upon the yield point of the material.

Strength of Corrugated Zinc Roofing (Whittemore).

This cooperative investigation between this bureau and the American Zinc Institute of New York, N. Y., is to determine the safe load which can be put on roofing of this kind for a given spacing of purlins. This information is much needed by builders and even by manufacturers of corrugated zinc roofing. A number of failures of these roofs recently has shown that reliable values for safe loads are not available. The question of the proper use of this material is of great economic importance. Zinc is used very successfully in Europe and should find a place in roofing materials used in this country.

Girder Hooks (Whittemore, Stang).

The work on this investigation has been resumed. The results of the tests made last year are being prepared for publication.

Investigation of Strength of Welded Rail Joints (Sweetman).

The bureau, in cooperation with the American Railway Association and American Bureau of Welding, is preparing to conduct a portion of an investigation regarding strength of welded rail joints of various types, such as are used in street railway systems. The bureau has undertaken to determine such properties as tensile strength, electrical conductivity, and impact resistance.

To date the bureau has conducted several tensile tests on welded joints of various types in order to determine a satisfactory means of gripping the specimen in the testing machine. In order that the rail ends may be gripped in the large Emery testing machine it is necessary to remove a portion of the rail head and flanges and rivet

to the rail web such filler plates as may be necessary to give the required section area. The result of these tests showed that in cases where the oxyacetylene blowpipe had been used in removing the head and flanges, the specimen broke in nearly all cases at the end and not by failure of the weld. This was due to cracking of the material adjacent to the cut by the severe heating action of the blowpipe. In the case of specimens from which the head and flanges had been removed by machine tools this trouble was not experienced, but the expense of preparing the ends by machine tool methods is great. The committee has adopted a method of gripping used in the testing laboratory of a large rail manufacturing company. This method requires no special end preparation. The apparatus necessary to make use of this method consists of pulling heads having a tapered opening similar to the head of a universal testing machine and tapered wedges which fit the contour of the rail. The manufacturers interested in this investigation are supplying the special heads and fixtures which will be used in connection with the large Emery testing machine.

Crinkling Stresses in Steel Tubing (Greene).

A large number of tests have been made to determine the mechanical properties of steel tubing manufactured in America and England for the purpose of selecting material and for comparing the uniformity of properties of the two makes. In addition, a few column and combined tests have been made and it is intended to continue the tests until satisfactory results have been obtained.

Riveted Joints (Johnston).

A series of tests to observe the behavior of riveted joints under working stresses is being made for the Bureau of Construction and Repair of the Navy Department. The joints are of different form and construction and are of three weights of material, of three grades of material, and several size rivets. They are 22 inches wide and will contain as many as 20 rivets on one side of the joint. The present schedule contemplates 99 tests.

For this work the optical strain gauge has been devised. Three trial joints are being made at the Naval Gun Factory, and it is expected that the tests will be started when the joints have been completed.

Bibliography on Riveted Joints (Stang).

A bibliography of technical publications on riveted joints has been prepared, which includes about 230 references. English, French, and German articles published in the last 10 or 15 years were carefully read, and the most useful articles selected.

The strength of riveted joints, obtained either by computation or experimental work in the testing laboratory, received particular attention. The practical aspects of the question have not been overlooked and helpful information contained in the trade journals has been included.

Tests of Members of Fleet Airship "No. 1" (Johnston).

During the year an investigation of the strength of various members of Fleet Airship *No. 1*, United States Navy, has been completed.

In all, 147 full size girder members, duplicates of the members used in the airship, were tested, each girder type being tested in triplicate, generally in both 5 and 10 meter lengths, and as either a free-end column, simple beam, or combined beam and column. The test specimens were fabricated of duralumin at the Naval Aircraft Factory, Philadelphia, Pa.

The failures were remarkably consistent, both in type of failure and in failing load for any particular type of girder. Further, practically all failures were elastic; that is, depended on the modulus of elasticity of the material or its stiffness rather than upon its other physical properties, and were, in general, of the type expected from previous knowledge of the behavior of such specimens. There were no failures of details, such as riveting lattices, etc., and throughout the entire series there was no evidence of brittle or inferior material having been incorporated in any part. The tests gave assurance as to the strength of the principal structural parts of the airship and furnished valuable data for future work.

Riveted and Welded Joints (Tuckerman).

A report on these tests made for the American Bridge Co. has been prepared for publication in one of the engineering journals.

Investigation of a Process for Seasoning Wood (Whittemore).

A preliminary investigation was conducted on a process for seasoning or drying wood. The investigation included tests on several kinds of hard and soft woods used in commercial work, specimens of which were tested when in partially green and kiln dried conditions for comparison with specimens which were treated by the process. The conclusion drawn from this work was that the process might be used to dry lumber to a condition suitable for use in a shorter time than by kiln drying.

Investigation of Strength of Welded Pressure Vessels (Whittemore).

In cooperation with the committee on welded pressure vessels of the American Bureau of Welding an investigation of the strength of welded pressure vessels has been conducted. This investigation was planned to obtain information on methods of making acceptance tests which would assist the boiler code committee of the American Society of Mechanical Engineers in preparing their Safety Code for Pressure Vessels. In general, the tanks were stressed under hydrostatic pressure until rupture occurred.

The following conclusions have been drawn from the test results: The double V welds were much stronger than the single V welds; the butt welded heads were stronger than the inserted heads; a hammer test can not be relied upon to show more than a few exceptionally defective welds; hydrostatic pressure $1\frac{1}{2}$ times the working pressure showed only a small number of imperfect welds, even when the hammer was used; hydrostatic pressure sufficient to stress the shell to the yield point will show a large proportion of imperfect welds.

The results of the tests made at the Bureau of Standards will form part of the report of the pressure vessel committee, to be printed by the American Bureau of Welding.

2. CEMENT, CONCRETE, CONCRETE MATERIALS, BUILDING STONE.

J. C. Pearson.

General Concrete Investigations (Pearson, Slater, Hitchcock, Dwyer, G. A. Smith).

All the general studies of concrete conducted by the bureau are classified under this heading, including tests of an investigative nature for the Government departments, and limited investigations of materials and methods of test. The most important of these studies during the year include a further development of the method of measuring consistency by means of a flow table of improved design, an investigation of the inundation method of measuring sand, completion of a cooperative series of tests on accelerators conducted under the auspices of the American Society for Testing Materials, completion of an investigation of the cause of failure of artificial stone in southern California in cooperation with the U. S. Geological Survey, and the development of a penetration test for measuring the workability of concrete mixtures. In addition, somewhat extensive studies have been made of three special cements, two of them produced and marketed in European countries, and numerous tests of concrete and concrete materials have been made for the U. S. Reclamation projects, for the Wilson Dam, Muscle Shoals, Ala., and for the Key Bridge and the new aqueduct, Washington, D. C.

Toward the close of the fiscal year, the bureau began a series of laboratory tests supplementary to the field tests of concrete being conducted under the auspices of the joint committee on concrete and reinforced concrete, in cooperation with the Associated General Contractors and the Portland Cement Association. The field tests are under the direction of W. A. Slater of this bureau, and are designed to show whether it is possible with a reasonable degree of care to secure concrete having a strength substantially in agreement with that required for the design. These tests are being made on a reinforced concrete building which is being built by Stone & Webster (Inc.), for the Victor Talking Machine Co., at Camden, N. J.

Improved Flow Table for Measuring Consistency of Concrete (Pearson, Hitchcock, Dwyer).

Progressive improvement has been made in the design of this instrument, which is now regarded as an indispensable part of the equipment of every concrete testing laboratory. The principle of the flow table was covered in a patent issued to C. M. Chapman in 1913, but the device in essentially its present form was developed by G. M. Williams in 1919, at that time an employee of the Bureau of Standards. The latest type of instrument embodies heavy all-metal castings, after a design by the Bureau of Public Roads. While the flow table has not yet been standardized, the new table eliminates most of the objectionable features of the earlier tables, and should be generally acceptable. The table is illustrated in a paper on the "Inundation method of measuring sand for making concrete," Proc. A. C. I., and the method of operation is described in detail in a paper on "A penetration test for the workability of concrete mixtures" presented before the American Society for Testing Materials, June, 1923.

Inundation Method of Measuring Sand (Slater, G. A. Smith).

The variation in the quantity of moisture carried in sand at different times causes important variations in the consistency of concrete in which the sand is used and also causes appreciable variations in the quantity of sand which a measure will hold when compacted in a standard manner. It has been found that a very large portion of these variations can be eliminated by measuring the sand in water; that is, by filling the measuring vessel about half full of water before filling it with sand. A series of tests was carried out to find out how satisfactorily the method could be used and to try it out in the actual making of concrete specimens. By shoveling sand into water in the measuring vessel very nearly constant quantities were obtained, regardless of the amount of moisture originally contained in the sand. By using both sand and water as measured by the inundation method and using the same quantities of cement and coarse aggregate concretes were obtained showing remarkable uniformity in consistency and strength. The results of these studies were presented before the American Concrete Institute in January, 1923, and appear in a paper by G. A. Smith and W. A. Slater in the Proceedings of the Institute, Volume XIX, 1923, page 222.

Tests of Accelerators (Pearson, Hitchcock, Dwyer).

The bureau participated in a series of tests of commercial and proprietary accelerations of the calcium-chloride type involving the making and testing of about 300 concrete and 400 mortar specimens. These tests were conducted under the auspices of the American Society for Testing Materials in cooperation with a number of laboratories. The results of the tests confirm and supplement the information previously published by the bureau on this subject and demonstrate quite conclusively that the early strength of concrete is increased considerably by the use of calcium chloride admixtures, but under damp storage conditions this increase does not usually extend beyond the 28-day period. The report of these tests appears in the annual report of committee C-9, A. S. T. M., for 1923.

Disintegration of Concrete Due to Altered Feldspar Aggregate (Pearson, Dwyer).

Extensive and rapid disintegration of an artificial stone widely used in Los Angeles a few years ago led to a joint investigation by the bureau and the United States Geological Survey. The quarries from which the aggregate was obtained were inspected, samples were procured, and specimens were made therefrom and exposed to the weather in Washington, D. C. The usual physical tests of the specimens were satisfactory, yet pronounced disintegration of the exposed specimens occurred within a year. Mineralogical examination showed that the aggregate was an altered feldspar, the disintegration being due primarily to laumontite. There was nothing in the case to give rise to any question concerning the suitability and durability of unaltered feldspar as a concrete aggregate. In fact, the latter is extensively and satisfactorily used for this purpose in various parts of the country. This investigation was reported in a paper, "An interesting case of dangerous aggregate," by J. C. Pearson and G. F. Loughlin, Proc. Am. Conc. Inst., Volume XIX, 1923, page 142.

Workability of Concrete Mixtures (Pearson, Hitchcock).

An investigation of considerable importance has been launched during the year by the adaptation of a simple penetration test to the measurement of the workability of concrete mixtures, as distinct from consistency or flow, a property measured by the flow table previously described, and varying with the quantity of mixing water used. It has been found that the penetration test gives results agreeing with the judgment of experienced operators as to the comparative workability of different mixtures, and while further refinement and extension of its application is needed, it has brought out some very interesting facts. Thus the workability of a concrete mixture is found to depend more on the nature and proportions of the solid ingredients than upon the amount of mixing water, and the effects of various powdered admixtures can be readily compared. The test is fully described in a paper, "A penetration test for the workability of concrete mixtures," by J. C. Pearson and F. A. Hitchcock, presented to the American Society for Testing Materials, June, 1923.

Durability of Sewer Pipe (Pearson, Furlong).

An investigation of the condition of clay and cement sewer pipes in the city of Los Angeles was undertaken in April, 1922, in cooperation with pipe manufacturers and the engineering department of the city of Los Angeles. Studies thus far have been confined to the sewerage of Los Angeles, but real progress has been made in determining those elements that may be injurious to the system. Test sections have been installed in various operating lines in the city, and exposure tests of clay and cement pipe have been made in man-holes so distributed as to cover practically all typical conditions. Inspections have been supplemented by extensive chemical studies, both in the field and in the laboratory. A progress report on the year's work has nearly been completed.

Cement Stucco (Pearson, Hitchcock).

Measurements of the stucco panels erected last year and described in the last annual report have been continued. Unfortunately these panels developed faults which were not anticipated and which masked the comparative values which they were designed to furnish. On the other hand, they indicated plainly some of the precautions which must be taken in the application of stucco to frame if satisfactory results are to be obtained; they also suggested that such factors as curing and the intervals between coats are more important than has been considered the case heretofore. If the cooperation of the industries can be obtained these indications will be followed up by a series of further tests next year with a view to developing the most dependable specifications for stucco on frame structures.

Concrete House Construction (Pearson).

Some further data on concrete house construction have been collected during the past year, but preparation of the general report on the subject has been set aside for more pressing matters. However, certain aspects of the concrete house idea were embodied in a paper before the American Concrete Institute, January, 1923, entitled "Thoughts on Concrete Houses," by J. C. Pearson. (See Proc. Am. Conc. Inst., Vol. XIX, 1923, p. 167.)

Durability of Concrete in Alkali Soils (Pearson, Furlong).

The chief item of importance in connection with this investigation was the installation of a new experimental drain near Montrose, Colo., consisting of 76 concrete drain tile treated with various bituminous compositions, either as coatings or penetrative treatments. This drain was installed in the alkali patch at North Mesa Siphon in October, 1922, by E. H. Berger, of the chemistry division. In addition, a section of the experimental drain at Montrose laid by the bureau in 1913 was inspected. A number of replacements were made in this drain in 1915, and the concrete blocks were exposed to alkali at Grand Junction, Colo. In general, the action of the alkali has been progressive, the disintegration being further advanced than at the last inspection in 1919.

Mr. Berger also visited and assisted in the examination of the concrete specimens installed by the Portland Cement Association at Medicine Lake, Florence, S. Dak., and at Montrose, Colo. While these exposures were only one year old at the time of this inspection, they largely dispose of any hope that integral waterproofing compounds can be regarded as effective against alkali attack.

Fineness Investigations (Pearson, Hitchcock, Sligh)

No further development work has been done with the air analyzer, although its application has been extended to new materials during the past year. A firm of engineering specialists has requested permission to commercialize this apparatus, and it is hoped that a portable and compact instrument will soon be available to the numerous industries and testing laboratories in which it can be used to advantage. As an indication of its general usefulness, the following is an incomplete list of materials which are for the most part beyond the reach of testing sieves, but which have been successfully classified by the analyzer: Cements, paint pigments, fine molding sands, copper and other metallic powders, carbon powders, clays of various types, pulverized quartz, feldspar, alundum, pumice, emery, and other abrasives; whiting, flue dust, potash treater dust, insect powders, hydrated lime, graphite, plaster of Paris, and basic magnesium carbonate. With the exception of one or two materials exhibiting peculiar properties, practically all the finely divided or pulverized materials which have been tested, and of which a considerable portion of the individual particles are between 0.1 and 0.01 millimeter in size, can be successfully separated by means of the analyzer.

Standard Fineness Samples (Sligh).

Neither a descriptive circular nor a suitable standard fineness sample for testing sieves of the United States standard series has yet been prepared, contrary to the expectations of a year ago. Lack of personnel and pressure of routine testing has displaced these important matters, but they can hardly be postponed another year. There is a distinct urgency for the preparation of samples of standard fineness for testing other sieves than the No. 200, particularly for the finer sieves, because it has been demonstrated that a sieve may not conform in every respect to the specifications and still apparently give as good results as one which does. The criterion is a test of the sieve on a sample of standard fineness, and, in general, a sieve so tested and

furnished with a correction is entirely suitable for control work, if not for standardization purposes. Under this heading may be mentioned a considerable amount of cooperative work in the testing of sieves and molding sands for the joint committee on molding sand research of the National Research Council; also the calibration of 27 sieves from nine different laboratories cooperating with committee D-5 on coal and coke of the American Society for Testing Materials, and participation in the fineness determinations of pulverized coal for that committee.

Standard Cement Samples (Sligh).

The bureau prepares and keeps on hand for issue standard fineness samples of cement for checking up No. 200 sieves. They are supplied in two degrees of fineness and are issued in sealed glass jars, each jar containing about 160 grams, enough for three 50-gram sieve tests. A price of 50 cents, sufficient only to cover the cost of preparation, is charged for each jar. With these samples No. 200 sieves may be compared with the standards of the Government and corrections to these standards determined. These samples are also used by the bureau in checking up its own sieves and in the determination of corrections for No. 200 sieves submitted for certification. A new sample, 46*i*, has recently been prepared, of which 78 per cent passes the No. 200 sieve. The other sample on hand is 47*c*, 89.2 per cent passing the No. 200 sieve. During the year very few of sample 47 were issued. About the same number of sample 46 was issued as in the preceding year. There was an increase of nearly 200 per cent in the number of No. 200 sieves for which corrections were determined, as compared with the year before.

General Work in Reinforced Concrete (Slater, G. A. Smith, Wade).

In addition to the preparation of a number of papers referred to in the list of publications issuing from this section, a great deal of time has been given to committee work of the various engineering societies. In particular may be mentioned participation in the work of the joint committee on standard specifications for concrete and reinforced concrete, and of the special committee on reinforcing steel, functioning under the auspices of the American Society for Testing Materials in cooperation with manufacturers, the joint committee, and the Bureau of Standards. A number of new and revised municipal building codes have been submitted to the bureau for criticism, in which studies of the design requirements are a part of the work coming under this heading. Progress has also been made in the analysis of data inherited from the Shipping Board, particularly on tests of ship frames, the effect of direction of slab reinforcement, and shear in reinforced concrete beams.

Test of Reinforced Gypsum Roof Slab (Slater, G. A. Smith).

At the request of the Bureau of Yards and Docks a reinforced gypsum roof slab designed according to the "Marks system" of roof construction was tested at the site of the Gallinger Hospital. This slab was 18 feet long, 8 feet wide, and $3\frac{1}{8}$ inches thick and was supported in such a manner as to give three spans of 6 feet each. Concentrated loads, which were equal to the designed live load, were applied at the one-quarter points of each span. After the designed load had been placed, the load on the center span was increased to

approximately three times the designed live load. The load was left in place for about six weeks, during which time deflections of all spans increased gradually. The action of the slab was generally satisfactory, even though the slab was not as dry as it would probably have been had it been sheltered from the weather.

Bond Tests of Dudley Deformed Bars and Plain Round Bars (Slater, G. A. Smith).

At the request of the Assistant Secretary of Commerce a study was made of the effect of Dudley reinforcement bars in resisting bond stresses in concrete as compared with the effect of plain round bars. Tests were made on beams reinforced with Dudley round, Dudley square, and plain round bars, and on pull-out specimens. At first slip in the pull-out specimens the Dudley bars in most cases showed smaller bond resistance than did the plain bars, but at the maximum load the bond stress was somewhat greater. In the beam tests similar results were obtained. As in other investigations, the round bars were found to be more effective than the plain bars.

General Investigation of Building Stones (Kessler).

The work in connection with this investigation has been confined chiefly to the weather-resisting qualities of limestone and sandstone. The laboratory work is being supplemented by field studies of the stone in structures. Inspections have been made during the year of numerous buildings in 12 cities of the East and Middle West. The purpose of the field studies is to obtain data on the weathering of the various types of stone under actual conditions of use. This will serve as a basis for interpreting the results of weathering tests.

A few minor investigations have been made during the year when the need for certain information was urgent. One of these was the study of a mica schist from Alta Vista, Va., for use in a Government breakwater. Studies were made of several samples of sandstone from the old Government quarry on Aquia Creek, Va., and neighboring deposits to determine the possibilities of the material for present-day needs. This material was rather extensively used in the first Government buildings, viz, the Capitol, White House, Treasury, and others, but its use was discontinued when better transportation facilities made more desirable materials available. This study indicates that some of the strata yield stone of reasonably good quality. A company has been organized and a quarry is being developed in the vicinity of the old Government quarry. Numerous tests were made on the slate submitted for use in the bottom of the reflecting pool of the Lincoln Memorial. A series of compression tests is being made for the Bureau of Mines to determine the relative strength of mine pillars of various heights.

An important development in connection with the work on building stone during the year has been the placing of a research associate at the bureau by the Indiana Limestone Quarrymen's Association. The associate works on the problems which are of general interest to all concerned with the use of Indiana limestone, and the results will be available, as the studies are completed, in the form of the regular bureau publications. A rather extensive program has been formulated for this work, which includes several lines of research that have heretofore received little attention. Among these

are fatigue and permanent distortion of the stone under continuous loading, the relative bearing power of stone and other materials when loaded under the conditions found in modern construction, the bonding of various mortars to limestone, and the bond of mortars to stones which have been waterproofed before setting.

Exposure Tests on Colorless Waterproofing Materials (Kessler).

The purpose of this study is to determine (*a*) the relative effectiveness of various materials in keeping the stone from absorbing water, (*b*) the life or period of effectiveness of the materials under exposure to the weather, (*c*) the relative effectiveness on various textures of stone, and (*d*) the effect on the appearance of the stone. Many of the tests have been in progress about two and one-half years. A report is in process of publication which gives the results of two years' exposure. This will probably be available during the present year.

The majority of the treatments have shown considerable deterioration during two years of exposure. A few, however, are giving excellent results after this period of weathering, while some of the materials showed practically no waterproofing values from the start. The tests on different textures indicate that waterproofing materials which give good results on coarse or medium textures may not prove at all satisfactory on very compact stones. Practically all of the materials experimented with produced more or less discoloration when applied to the stone which remained during several months' exposure to the weather. After about a year, however, this, in all cases, had faded out, leaving a cleaner appearance than the untreated stone. This was due to the fact that the waterproofing served to prevent the dust and soot from entering or lodging in the pores of the stone.

Weathering Tests (Kessler).

The frost-action tests, which consist in repeatedly freezing the specimens while nearly saturated with water, are carried to the point at which the stone is practically destroyed. Some of the specimens of limestone began to disintegrate at less than 100 freezings, while others have withstood nearly 1,000 freezings without showing any appreciable disintegration. The work on sandstone has not been carried as far as that on limestone, but far enough to indicate that the weaker sandstones are somewhat less resistant to frost action than the poorer grades of limestone, while some of the better grades of sandstone have passed 500 freezings without marked signs of decay.

A series of artificial freezing tests is being made in which common salt is allowed to crystallize in the pores of the stone. This is done by soaking the specimens in a solution of the salt and afterwards drying them. The formation of salt crystals in the pores has a similar action to that of ice but is more severe. Hence, disintegration results in a much shorter time. This test seems to offer a more expeditious means of determining the resistance of stone and similar materials to frost action, although the test requires more extensive study to determine whether it is entirely comparable to frost action. A similar method has been proposed and sometimes applied by using sodium sulphate instead of common salt. This gives a more severe action than sodium chloride, and on some materials it causes disinte-

gration when not allowed to crystallize, which indicates a chemical action. Hence, it is not believed that the sodium-sulphate test is entirely satisfactory as an accelerated test for durability of stones exposed to the weather.

Elastic Pointing and Calking Materials (Kessler).

The work being done on this subject consists in testing the tightness of joints, which have been calked with various materials, under continuous exposure to the weather. A few new materials have been added to the tests which were started during the past year. Some of the materials have shown considerable shrinkage and cracking during one year of weathering.

Discoloration of Stone Masonry (Kessler).

This subject has been given some attention during the past year. Various cements have been tested for setting limestone and tests are in progress to determine the feasibility of preventing stains by coating the exposed surface of the masonry with colorless waterproofing materials. Some attention has been given to methods of removing stains from masonry. A case of staining on the granite steps of the Lincoln Memorial had caused so much annoyance that the commission in charge was considering the removal of the stained blocks at considerable expense. The bureau was called into consultation, and the stains were successfully removed at a very insignificant cost.

Caustic Magnesia Cements (Bates, Young, Rapp).

As a result of the laboratory testing of a large number of commercial composition floorings, a specification was drawn up which was presented to the National Association of Oxychloride Cement Manufacturers as tentative. In the preparation of these specifications, the data which the bureau has accumulated on caustic magnesia and its properties were also used in arriving at the suggested specifications.

The bureau has been cooperating with a number of producers of domestic caustic magnesite and with certain users in formulating specifications for caustic magnesia, to cover its uses in the flooring, stucco, and ship-decking industries. This is at the present time under consideration by those interested in the matter.

The large test panels of commercial caustic magnesia stucco, which were erected a year and a half to two years ago, are still under observation. Their behavior up to the present time has been perfect in every respect.

Constitution of Portland Cement (Bates, Young).

The investigation which was being conducted at a commercial cement plant on the effect of burning and composition on the finished cement was completed during the year so far as plant operation was concerned. The study was one of extreme interest and the data which are now being accumulated indicate that very valuable information has been obtained. Notwithstanding that the compositions of the various cements varied as much as 5 per cent in silica content, 2 per cent in alumina content, and 5 per cent in the lime content, all but five of the cements passed the specifications as now in force. At the end of three months, however, these five

cements which gave low tensile strength had acquired a strength in excess of that acquired by many of the cements which had passed the specifications. In view of the fact that specimens have been made which will not be tested before the end of 10 years, conclusive data will not be available for some time. However, it is hoped to be able to present the data which will be at hand at the end of one year, together with preliminary conclusions. It is hoped that these data will give some information in regard to the action of "alkali" on cements, since the concrete specimens are being stored in not only a damp closet but in the dry atmosphere of western Texas and soil highly impregnated with alkali.

In view of the agitation in regard to the high alumina cements, which are covered in Technologic Paper No. 197 of this bureau, it was deemed advisable to inaugurate further investigation of these cements. However, the work has not progressed further than the making of some very preliminary burns, in which the compositions approached closely that of the similar type of cements being manufactured in France. Raw material in the form of bauxite from Georgia has also been obtained, which will be used to manufacture this cement in a rotary kiln. The resulting cement will be tested particularly for its resistance to sea-water action on concrete.

Cement Inspection (Dwyer, Oscar, Moyer, Furlong, John).

The quantity of Portland cement tested by the bureau and packed and shipped under the supervision of its inspectors to Government projects during the fiscal year was 19.5 per cent greater than the amount handled during the preceding fiscal year. The monthly totals are compared in the following table:

SHIPMENTS OF BUREAU TESTED AND CERTIFIED CEMENT (BARRELS).

	1921-22	1922-23		1921-22	1922-23
July.....	71,416	42,918	April.....	43,970	85,833
August.....	63,853	46,851	May.....	45,156	103,090
September.....	67,528	28,014	June.....	46,064	103,349
October.....	72,355	42,536			
November.....	46,809	40,850		593,845	737,601
December.....	44,675	46,444			
January.....	27,624	54,418	Rejected for failure to meet specifications.....	51,124	43,800
February.....	21,476	69,108			
March.....	42,969	74,185			

Miscellaneous Tests.

In addition to the mill inspection work, 111 samples of cement submitted by Government offices and State institutions were tested. Some of these were intended for comparisons, others were referee cases. Field specimens of concrete have been submitted from a number of Government projects, totaling nearly 800, the majority coming from the Wilson Dam, under construction at Muscle Shoals, Ala. Including the work of the branch laboratories at Denver and San Francisco some 550 miscellaneous samples have been tested, including concretes, aggregates, cement products, water, paints, asphalts, galvanized metals, oils, waterproofing compounds, and building stones. In connection with tests of accelerators previously mentioned, a number of concrete cylinders containing calcium chloride, and exposed to

the weather in 1917 and 1918, were broken in the latter part of the fiscal year. The embedded rods were generally in good condition, although localized spots of rust were observed, apparently where voids occurred on the surface of the steel.

3. LEATHER, RUBBER, ETC.

P. L. Wormeley.

Chrome Sole Leather (Bowker, Geib).

A comprehensive investigation to determine the comparative durability and utility value of chrome-tanned sole leather and vegetable-tanned sole leather has been completed. Comparative wear tests involving natural chrome sole leather and samples which had been stuffed with paraffin, hard greases, and mineral fillers gave results which lead to the following conclusions: (1) Natural chrome leather will wear twice as long per unit of thickness as vegetable tanned leather, but will not hold its shape and is not water resisting. (2) Chrome leather stuffed with paraffin will outwear vegetable leather in nearly the same ratio as does natural chrome. It holds its shape slightly better, but remains resistant to moisture penetration for only a short time. (3) Chrome leather stuffed with hard greases and mineral fillers will wear about 30 per cent longer than vegetable leather. It is firmer, more waterproof, and holds its shape better than natural leather and that containing paraffin. (4) As a general conclusion, it may be stated that chrome sole leather will wear approximately twice as long as vegetable sole leather per unit of thickness, but that in order to secure firmness and water-resisting properties comparable to that of vegetable leather the wearing quality of the chrome leather must be sacrificed to some extent.

Synthetic Tanning Materials (Wallace, Wolesensky).

Observations made on these materials during the year have shown that by themselves they are not suitable for making leather, since they lack the filling properties of ordinary vegetable tanning materials. Tanning tests using blends of the ordinary materials and the synthetic materials show that the latter are an aid to penetration, the time required for striking through a heavy hide being cut in half. The use of these materials in the extract wheels aided penetration and also had a bleaching effect. A study of the plumping effects of a blend of vegetable tanning and synthetic materials showed that some had a decided plumping effect, while others after a certain point actually depressed the hide. Some of the samples had a solubilizing effect on the insolubles of certain vegetable tanning materials when blended with the latter in certain proportions. The composition of the synthetic tanning materials is such as to make their economic importance of limited value since care must be exercised in their use, and even then only a small amount can be used in combination with the ordinary vegetable materials. A comprehensive program of research has been started relative to the production, process development, and application of these materials, and the possibilities of using some of the coal-tar derivatives in combination with cheaper materials in order to produce a blend which will in itself be satisfactory for converting hides into leather will be studied.

Leather from Hogskins (Bowker, Wallace).

Hogskins offer a large potential source of leather, it being stated that the annual slaughter of hogs is about 60,000,000, the skins of which for the most part are sold as meat. Hogskins contain large amounts of natural fats which seriously interfere with the proper tannage of these skins, especially by the chrome process. Investigations relative to the quality of the leather made from hogskins which had been entirely degreased prior to tanning were made during the year. Tanning, chemical, and physical tests were made involving hog, calf, sheep, and goat skins in both the degreased and natural conditions. As a result of these tests it is believed that leather made from degreased hogskins and sheepskins can be brought into general use for shoe uppers, thereby presenting larger sources of raw skins in the case of hog and a new use for sheepskins not seriously considered formerly.

Colon Leather for Diaphragms (Bowker).

Samples of specially prepared colon leathers have been found to be satisfactory for use as slack diaphragms in certain aeronautic instruments. Tests made have shown that these materials can be depended upon to repeat their performance under similar conditions, that they are not affected by temperature over the range in which use is likely, and do not have so high a permeability as to be unsuited for use. This latter is a very essential property for any material to be used as a slack diaphragm.

Shoes (Bowker).

Assistance was given the United States Public Health Service in connection with the development of standard shoes for letter carriers for both winter and summer wear. This work involved tests for quality of the leather used, study of the construction of the shoes, and actual service tests to determine whether any inherent weaknesses would develop.

Comparisons were made on different shoes for the New York police department relative to the quality of materials used and the construction.

A contact with the National Committee on Prisons and Prison Labor was established, as a result of which a report has been made relative to the quality and construction of shoes made in one of the State prisons.

Power Losses in Automobile Tires (Wormeley, Holt).

This investigation has been continued and tests made on approximately 100 tires of different makes and sizes. The results of these tests have been compiled for publication as a technologic paper. A number of manufacturers have availed themselves of the special tire-testing equipment at the bureau in order to determine the effect of new features in the design of tires.

Endurance Tire-Testing Machine (Wormeley, Holt).

The operation of this machine has been continued, and numerous tests made at varying axle loads and air pressures with different types of test wheels in order to arrive at a condition comparable with road service. In this work the bureau has had the cooperation of the various Government departments, in particular the Post Office De-

partment, in checking the bureau's laboratory results with road tests. Advice has likewise been furnished by the Rubber Association of America and by several individual manufacturers. The results to date show that the conditions of test and the type of test wheel are of vital importance. Tentative test conditions have been established and are being verified by tests on tires from representative manufacturers.

Accelerated Aging Test for Rubber Goods (Holt, Boone).

A continuation of this investigation has shown the desirability of including such tests in many of the specifications for rubber goods. This is being done as rapidly as the bureau is able to establish satisfactory test conditions for different types of materials.

Jar Rings for Canning (Boone).

This investigation has been completed and the results transmitted to the manufacturers interested. The tests indicate that rings purchased under the present specification should give satisfactory service.

Milking Machine Rubbers (Collier, Boone).

At the request of the Department of Agriculture an investigation was conducted to determine the reason for the rapid deterioration of rubber used with these machines. The bureau's tests showed conclusively that this trouble could be eliminated by the removal of the butterfat thoroughly before sterilization.

Insulated Wire Investigation (Holt, Boone).

This investigation is being conducted in cooperation with the chemical and electrical divisions at the request of the Signal Corps of the Army. The different kinds of rubber, gutta-percha, balata, etc. (along with numerous compounding ingredients), are being studied in order to determine the best materials for insulation purposes consistent with cost and availability.

Specially Prepared Rubbers (Holt, Anderson).

Advances which have been made in the rubber industry in methods of preparing rubbers from the latex have made it necessary for the bureau to follow such changes with a view to maintaining proper standards for rubber goods. Preliminary experiments which have been conducted with these specially prepared rubbers have shown some quite surprising results in the way of possible increases in tensile strength.

Insulating Tape (Boone, Cook).

This investigation has been continued with tests on the tapes which have aged for six months and one year. A report covering the first six months was sent to the different manufacturers.

Rubber Analysis (W. H. Smith).

The analysis of rubber goods, representing material purchased by various Government departments, is a necessary and important function of the bureau. For this class of materials certain routine methods may be followed, but in many cases it is necessary to use revisions of the ordinary procedure.

A method of analysis, depending on the selective solvent action of mineral oils, has resulted in greater accuracy than was possible in

the past. By this method the fillers, especially decomposable fillers, may be determined definitely for a great variety of compounds.

An attempt is being made to determine mineral rubbers by a new method of procedure. Experimental work on rubber accelerators is also being carried on.

The methods of analysis proposed by this bureau and adopted by the American Chemical Society, and substantially by the American Society for Testing Materials, have been submitted to the Federal Specifications Board for its approval.

4. TEXTILES.

F. R. McGowan.

Heat-Retaining Properties of Fabrics (Sale).

The work carried over from the last fiscal year relating to the design of apparatus and most suitable method of testing the comforting value of blankets, which composed three distinct measurements, has been finished, and a detailed publication on the method of test and description of apparatus has been prepared. The problem itself will require additional work in the line of procuring fundamental data in order that the results may be expressed in terms which will make them most useful to the manufacturers of blankets and clothing materials.

Pima Cotton (McGowan, Mercier).

The investigation as to the use of this material, as outlined in the last annual report, is still under way, since mail sacks made from this cotton are still under service test by the Post Office Department. Examination from time to time has indicated that no marked changes have occurred in the quality, and there has been no marked decrease in the strength or usefulness of the bags.

Sheeting (McGowan).

This investigation was carried on to determine the physical properties of sheetings, as obtained from commercial houses, in an effort to obtain standard specifications for sheeting. The work took into consideration 30 or more different types of sheetings, and after being tested the results were reported to the manufacturers submitting samples through the textile division of the Bureau of Foreign and Domestic Commerce, the latter having been instrumental in procuring the samples. From results of this work and surveys which have been carried out specifications were submitted to the Joint Committee on Research and Standardization of the Cotton Industry for their consideration. No reports of final adoption are available to date.

Appraisal of Textiles (McGowan).

The Veterans' Bureau was anxious to dispose of a large quantity of textiles. At their request the Bureau of Standards made an appraisal of this material. The survey included items ranging from cheese-cloth to heavy duck, bandages, towels, absorbent cotton, aprons, sheeting, and blankets.

Fish Lines (McGowan).

A recent publication of the Bureau of Fisheries on the effect of the available commercial treatments for preserving fish lines includes the

work on the physical properties of these lines made by this bureau. The publication shows the effect of the different preservatives on the life of the material, also their effect on handling by making the materials pliable or stiff, as the case may be. It is planned to carry this work further to include various other types of textiles used in the fishing industry.

Abrasion (McGowan).

The work on the investigation of the workability of the apparatus used to determine the abrasive qualities of fabrics was not in progress the greater part of the year. At the request of the Joint Committee on Research and Standardization of the Woolen and Worsted Industry the work was again started to cover one or two important problems of the wool industry. The investigation on the effect of the variables of the machine has not been completed. It has not seemed advisable to place this device before the public, inasmuch as the preliminary data have not been completed.

Stress/Strain Relations of Balloon Fabrics (Sale, Morris).

At the request of the Navy Department a series of tests was made on the outer cover cloth of large airships similar to the *ZR-1* to obtain fundamental data on the relations of the stresses in the covering. The work covered methods of application and the effect of different applications on the strength and serviceability of the material.

Standard Method of Testing Fastness of Color (McGowan).

Surveys have been made of available apparatus used for fading and for indicating the degree of fading of various colors on a number of textile materials. The work was undertaken at the request of the American Association of Textile Chemists and Colorists, whose purpose it is to obtain standard methods of testing fastness to light, washing, and other factors. The bureau is testing one set of specimens which was sent out by the association for the purpose of checking. This work is to be correlated with the project of standardization of dyes.

Conveyor Belts (McGowan).

At the request of the Post Office Department a further survey was made to obtain data which would enable that department to secure the most suitable belting for their purpose. Inspection at the New York post office indicated that in considering specifications for belting for that particular branch of service, account should be taken of a number of variables which enter into the life of the belt, such as the condition of the mechanical fixtures. As a result of the bureau's recommendations, specifications covering rubberized fabric and stitched canvas belts were drawn up by the Post Office Department in cooperation with the textile section.

Brattice Cloth (McGowan).

At the request of the Bureau of Mines, cooperative work has been started on the preparation of specifications for brattice cloth, specifications for application, and specifications for testing the material. A survey of the present materials used in the different mines, classified as to location and gaseous condition, was made by the Bureau of Mines; and later a survey of application was made by a repre-

sentative of the bureau. The matter has been placed before the manufacturers' advisory committee for their consideration. The plan as now outlined includes the introduction of fabrics made from hard fibers and an investigation of fire-resisting and water-resisting treatments.

Electrical Cotton Yarn (McGowan).

At the request of a manufacturer of magnet wire, a committee was formed composed of electrical wire manufacturers and cotton-yarn dealers for the purpose of drawing up a standard method of testing the physical properties of electrical cotton yarn. To date the committee has succeeded in drawing up standard methods of testing breaking strength, and is now working up a standard test to indicate the uniformity of winding of the yarns on the cheeses.

Sandbags (McGowan).

As an item on the preparatory program of the War Department, the substitution of cotton for jute sandbags has been turned over to the bureau. This requires a survey of the present containers available and also the possibility of utilizing paper yarns and textile fibers. The possibility of using bale wrappings has been entertained and can be brought about by the introduction of cotton wrapping for bale purposes.

Specifications for Federal Specifications Board (McGowan, Schoff-stall).

In general, in the previous formation of textile specifications by the various Government departments very little investigational work was used. This makes necessary a thorough study of each of the fabrics under consideration with a view toward forming an efficient specification based primarily on commercial materials. By commercial materials are meant those which are now being manufactured or those which will be by general agreement used as commercial standards.

A survey of all Government specifications for textile materials has been made, showing over 950 specifications covering over 1,500 separate materials. A complete file is being collected for consideration of each of the materials as they are taken up by the committee. After a tentative draft has been formed, it is referred to manufacturers' committees for comment. Committees representing the various parts of the textile manufacturing industry are being thoroughly organized to expedite the handling of this work. In the cotton industry, for instance, a small committee formed from the largest associations handles the specifications, referring them to the manufacturers of the particular product under consideration, which results in a complete survey of commercial practice.

From all these comments, criticisms, and collective data a tentative specification is formed, and after approval by the textiles committee and the commercial committee it is submitted to the board for adoption and promulgation.

Progress of the textile specifications is summarized as follows: There have been completed specifications for numbered duck and the measurement of hosiery; there have been submitted to commercial technical committees specifications for Army duck, shelter-tent duck,

dredging sleeve duck, denim, and sheeting; and the committee is now considering wool and cotton bunting, felt, and blankets.

In addition, some data and comments were prepared on type-writer ribbons and handed to a committee formed to consider them. Also, standard methods of test have been adopted by the committee and the various commercial committees.

Research and Standardization (McGowan, Schoffstall).

It is the desire of the bureau to be of maximum assistance to the commercial world, both through the introduction of research and standardization and through assistance in obtaining fundamental data, upon which standardization can be based. Along these lines the textile industry has been successfully approached and organized into one main committee known as the main advisory committee of the Bureau of Standards on research and standardization. This committee takes into consideration particularly the manufacturers of the industry, and the work should be broadened to include the jobbers, retailers, and allied industries. The main committee has met on three occasions. The last meeting was held on June 1, and resulted in the appointment of John P. Wood, of the wool industry, as chairman. The following associations have appointed advisory committees to work with the bureau on subjects of particular interest to them: The National Association of Wool Manufacturers; the American Association of Woolen and Worsted Manufacturers and the National Association of Woolen and Worsted Spinners have appointed a joint committee; the National Association of Cotton Manufacturers and the American Cotton Manufacturers Association have also appointed a joint committee; National Association of Hosiery and Underwear Manufacturers; Cordage Institute; Cotton Duck Association; Silk Association of America; National Association of Finishers of Cotton Fabrics; Association of Manufacturers of Window Shades and Shade Cloth; National Tent and Awning Manufacturers Association; Interstate Cotton Seed Crushers Association; American Association of Wool Blanket Manufacturers; and National Committee on Prisons and Prison Labor.

5. PAPER.

F. A. Curtis.

Thickness of Paper (Houston).

Disputes between the manufacturers and users with regard to the thickness of paper can usually be traced to a difference in readings of the instrument used to measure the thickness. To determine the magnitude of the difference that may result in the use of the types of dial micrometers commonly employed to measure paper, a number of instruments were calibrated against steel gauges and used to measure the thickness of several grades of paper. The micrometers were studied to ascertain the causes of the different readings on the same paper. The instruments were found to differ in form and area of contact, contact pressure, and in the amount of friction in the mechanism. To determine the effect of contact area and pressure, tests in measuring paper were made on commercial papers using contacts of different areas and with varying contact pressures. These

tests showed that the paper yielded to a greater extent with increase of pressure when the contact was larger than when small. Under the same pressure per square inch, but different contact areas, different readings of thickness were obtained. The mechanisms of the instruments were studied to determine the effect of the various designs on the contact pressure, the variation in contact pressure, and the accuracy and variance of the instruments. Specifications are given for a standard instrument. From a study of the mechanisms of instruments and the results of this investigation, it is felt that two or more types of the mechanisms studied can be used in instruments that will meet the specifications. The paper also contains specifications for a standard procedure to determine the mean thickness of a sample of paper. The investigation was carried on in cooperation with the gauge section, and the results appear as Technologic Paper No. 226.

Color of Paper (Lofton).

In connection with several investigations and also for mill control work, it has been necessary to develop a method for measuring the color characteristics of white paper in such a way as to obtain a comparative numerical figure. Through the courtesy of the paint section, an apparatus was available which had been developed for zinc white paint. The method was developed by Professor Pfund, of Johns Hopkins University. It is a method by which the color characteristics of white paint may be determined in terms of the capacity of the paper for diffusely reflecting red (625 meter wave length), green (550 meter wave length), and blue (460 meter wave length) light. The color characteristics of 21 samples of white paper were determined, and apparently all the samples tested are more or less deficient in the proportion of blue light reflected. Further investigation should be made as to the importance of whiteness and brightness and also the effect of the "finish" of the paper upon the test.

Relation Between Bursting and Breaking Strength (Houston).

A study of the curves of bursting and breaking tests on paper at different humidities indicates a striking similarity in the form and magnitude of the variations. It was believed that the data from these tests indicated similar properties of paper. For this reason, a study was made of the two test methods and the relation between the two was investigated. A special device was attached to a Mullen tester to permit the determination of the amount of deflection of the diaphragm, from which the stretch of the paper could be calculated. Tests were made on similar specimens on the Schopper tensile tester and the data arranged to indicate the possible relations:

$$\frac{\text{breaking strength}}{\text{elongation}} = \frac{\text{bursting strength}}{\text{elongation.}}$$

Although only a limited amount of data was obtained on account of the time available, the results indicate that the above relation is valid and might be used as a means of calibration of the Mullen tester. The results of this investigation were published in the Paper Trade Journal, March 29, 1923.

Breaking Strength Test (Houston).

There are a number of devices for determining this quality of paper, but there is little uniformity in the procedure as to width and length of the test strip, the rate of applying the load, and the time during which the specimen is under stress. A study of these various factors has been completed, using a number of different types of paper, the study being made with a 50-kilogram Schopper tensile tester, hydraulically operated. An examination of these data indicates that there is considerable difference in the amount of stretch when the factors are varied, but that, when only the strength is to be considered, the length of the specimen, within certain limits, is negligible and that the strength is almost proportional to the width. The results of this investigation were published in the Paper Trade Journal, March 22, 1923.

Brittleness of Paper (Houston).

The Mullen tester is used almost universally in this country for determining the bursting strength of paper and this factor is used, to a large extent, as a measure of the quality of the paper. It often happens, however, that a sheet may be so made or so sized that it will have a high bursting strength and yet show a very low tearing or folding strength. By means of two steel rollers, a crease is made under controlled conditions of pressure and time and the bursting strength is determined before and after such folding. The loss in strength under such conditions is an excellent indication of the brittleness of the paper. The grading of paper by this method is practically the same as that obtained by the Schopper folding endurance tester. The results of this investigation were published in the Paper Trade Journal, April 12, 1923. Further work is to be done to standardize the tester and the method of procedure.

Effect of Humidity on Paper (Houston, Kirkwood, Carson).

As in the case of textiles, most of the physical properties of paper are affected by changes in the relative humidity of the surrounding atmosphere. Various physical qualities of paper have been studied under relative humidity conditions of from 15 to about 85 per cent and the results were published in the Paper Trade Journal, April 12, 1923. The test data indicate that the bursting and tensile strengths are very similarly affected by changes of relative humidity, with a maximum at about 35 per cent moisture. Weight, tearing and folding strength, and expansion seem to increase steadily with increase of relative humidity. The investigation has opened up two questions: (1) What relative humidity should be standard for test, and (2) what is the relation between the actual strength of the individual fibers and the friction between or cohesion of the various fibers in the sheet?

Sizing Quality of Paper (Carson).

One of the most important and fundamental factors in the manufacture of paper is the process of sizing paper. In general, this process may be divided into two parts—engine or beater sizing and tub sizing. In the former case rosin is used almost entirely, although glue, starch, water glass, casein, etc., are sometimes used in addition. In the latter case glue, converted starches, or a mixture of the two are almost exclusively used, although these materials also affect other

properties of the sheet. In this study their effect on the resistance or partial resistance to ink and fluids is of especial importance. Before undertaking the study of the operation of sizing it has been necessary to develop a reliable test method. Some 18 methods have been more or less investigated, and a supplementary report was published in the Paper Trade Journal, September 7, 1922. It appears probable that different test methods will be necessary, depending on whether the paper is to be used for printing, for writing, or to be used in some process where the absorption must be accurately controlled. It would seem that sizing quality can not be defined truly in terms of either lateral absorption or normal absorption alone, but is to be judged as a result of the independent measurements of both.

Waterproof Test (Carson).

There is a considerable demand for a method of measuring the so-called waterproof quality of certain papers. This has been investigated and a method proposed which should be fairly reliable, but further work must be done to correlate the test data with the value of the paper under actual service conditions. A modification of the Stöckigt method for determining sizing quality is used as a means of determining the relative water-resisting quality of paper. The specimens are molded into a cup shape in the top of the bottle, having an inside diameter of about $1\frac{1}{2}$ inches. The "cups" are floated on a 2 per cent solution of ammonium thiocyanate (NH_4CNS) and three or four drops of a 1 per cent solution of ferric chloride (FeCl_3) is placed in the middle of each "cup." The time required for the pink or red coloration to set in is taken as a measure of the degree of waterproofing. It is believed that this method is more convenient and reliable than the methods usually employed.

Rubber Latex in Paper (Shaw, Bicking).

Due to the recent publicity given to a patent for the use of rubber latex in paper an investigation was made for the paper division of the Bureau of Foreign and Domestic Commerce. Rubber latex in a diluted form is put into the beater and it is claimed that this addition improves the quality of paper in regard to strength, finish, filler retention, etc. A series of runs was made with different furnishes and tests were made on the paper so made. A complete report of this study was published in the Paper Trade Journal, December 28, 1922. This report indicates that the increase in strength was within the natural variation of paper-making practice, that great care had to be exercised to prevent the agglomeration of the rubber into relatively large particles, and that in some cases the paper developed a pronounced odor on storage.

Aging of Rubber Latex Paper (Shaw, Carson).

In connection with experiments as to the use of rubber latex in paper it was found that it was difficult to obtain a complete extraction of resin and rubber from the paper and a separation of the two materials. The method used was to extract first with acetone to eliminate the resins and then to extract with chloroform. A special run was then made and extractions made daily. Successive analyses of the same papers with increasing age indicate a comparatively rapid oxidation of the rubber retained in paper as a result of

adding latex to the beater furnish. Within the limits of the investigation the oxidation was observed to be most rapid in the case of paper made of sulphite and soda pulp and least rapid in the case of rag papers. Complete oxidation in the case of the former was a matter of a few days, while in the latter case several months were required for the greater part of the rubber to oxidize. The results of this investigation were published in the *India Rubber World*, June 1, 1923.

Antitarnish Paper (Kirkwood).

Considerable difficulty has been experienced in the past as to a suitable method for determining whether a paper was suitable for wrapping polished metal goods. There seemed to be disagreement between the methods proposed. A number of samples were obtained, but before testing these the cooperation of the electrochemistry section of the electrical division was obtained. Strips of plated, pure, and sterling silver were wrapped with small pieces of the paper samples and the specimens were placed in jars under both dry and moist conditions. The tarnishing effect of the paper has not yet been determined, but as soon as the tests given above are completed the samples of paper are to be examined and tested. From other studies it is evident that sterling silver tarnishes more rapidly than pure silver. It is planned to prepare later a standard method for testing antitarnish paper.

Photomicrography of Paper Fibers (Lofton).

Although completed during the last fiscal year, the report on this investigation was not published until recently as *Technologic Paper No. 217*. It contains a description of some of the more important factors in the photomicrography of vegetable fibers, especially those used in the paper industry. Three types of light filters, with general directions for preparing them, are discussed. Suggestions as to the best type of photographic plates to use for photomicrographic work are given. Staining and preparing the material to be photographed are discussed and the value of photographs for permanent records and in the study and control of materials and mill processes is pointed out. The various discussions are illustrated by photomicrographs and diagrams.

Colored Micrographs (Merritt).

In connection with the microscopic study of paper fibers it has been found very advantageous to make projection drawings. Such projections and drawings bring out the characteristic markings much better than when the specimens are observed through the microscope in the ordinary way. By properly coloring or tinting these drawings useful charts are made available for reference and for research. The additional advantage of these drawings over photomicrographs is that selected fibers on fields may be placed together to bring out special characteristics. A series of such drawings is being prepared, both of the ordinary paper-making pulps and also of special woods and fibers. These drawings are being tinted to bring out the characteristic markings and will be of value not only for study but also to microscopists in the paper industry.

Methods of Fiber Analysis (Merritt).

In connection with the cooperative study by a committee of the Technical Association of the Pulp and Paper Industry work has been started on several methods of fiber analysis that have been proposed as standard. In the past the method used in any laboratory was largely dependent upon the individual microscopists, but there has been much discussion as to the relative merits of the "count" and "estimation" methods. Samples of known and unknown proportions of various fibers were prepared for use in this work. It is expected that procedure for standard test will thus be developed.

Chemical Hydration of Pulp (Shaw, Bicking).

In connection with a research organization some experiments were made to determine whether a certain amount of hydration could be produced by preliminary treatment with strong, cold caustic soda. Cotton linters were used, but the work was not carried far enough to develop any very definite conclusions. This work, however, showed the possibilities of a more thorough study of this subject, and a large amount of time could probably be saved if such a method could be developed. However, a great deal of laboratory work would probably be necessary before any definite paper-making trials could be made. This problem is, of course, closely connected with the fundamental study of cellulose.

White Water Waste and Recovery (Shaw, Bicking).

In connection with the work of the committee on waste of the paper industry cooperative studies were carried out at two book paper mills—Dill & Collins Co. and the Miami Paper Co. These tests were made to determine the amount of clay and fiber that was lost and also to obtain some information as to clay retention under actual mill conditions. These tests were exhaustive and were made during an actual commercial run of paper, and the data were used by the waste committee in their report to the paper industry. A supply of pulps and clay were presented by the Miami Paper Co. to permit of duplicate runs at the Bureau in order to develop a relation between the experimental mill and a large commercial machine. The experience and data obtained are chiefly of value in connection with the study of domestic and foreign clays.

Domestic and Foreign Clays (Shaw, Bicking).

There has been considerable delay in completing this problem, and it has been postponed from time to time to finish other work. The various runs made last year were of a preliminary nature and were of value in developing the technique and in obtaining preliminary information. However, the final runs are now being made on 5 domestic clays and 3 foreign clays in order to obtain mill data. These clays have been tested, and samples of the paper made are tested in the usual manner and also for color and finish. It is hoped that sufficient data will be available to determine the relative value of the two types of clay when color, amount of grit, retention in the paper, and cost are considered.

Condenser Paper (Shaw, Bicking).

In connection with the manufacture of power condensers, a lightweight paper approximating 0.005 inch in thickness is necessary.

The requirements for this paper are that it must be free from pin-holes and from conducting particles. Difficulty has been experienced in obtaining this paper, since most of the commercial papers contain approximately 30 to 40 such particles per square foot. An investigation was undertaken last year at the request of the General Electric Co. and satisfactory paper was produced here. A report of this study was published in *Paper Industry*, May, 1923. Considerable assistance was given by both the General Electric Co. and The Smith Paper Co., and special equipment was supplied by them. The chief requirement in making this paper, in addition to cleanliness, is the use of a stone or composition beater roll from which metallic particles will not chip off.

Glue for Coating Paper (Gottschalk).

Due to the probable increased price of casein, the National Association of Glue Manufacturers has established a fellowship to study the use of glue for coating paper. A number of years ago it was customary to use glue for this purpose, but with the introduction of casein glue was seldom used. For certain purposes casein gives a better coating, due to its water-resisting quality. Samples of glue have been obtained and preliminary studies are being made. A drying apparatus is to be added to the coating machine in order to reproduce mill conditions. It is planned to use the paper, under carefully controlled conditions, for both typography and lithography.

Flax Straw for Paper (Kellogg, Shaw, Bicking).

Last year the investigation of the possible use of flax straw and tow for paper making was undertaken. Very large quantities of seed-flax straw are available in the Northwest and in Canada. The problem was restricted to the study of the use of the "sulphate" process. This is an alkaline cook used for spruce, southern pine, etc., and the paper made from such pulp is commonly called kraft. A number of cooks and runs were made, using both the seed straw and tow produced from the seed straw. Very satisfactory results were obtained, and during the latter part of the year a number of cooks were made under industrial conditions in a sulphate pulp mill at Jaite, Ohio. There were a number of unfavorable factors present during these cooks, such as a dirty system, dirty water, etc., but the pulp was shipped to the bureau and runs were made. The quality of the paper produced was not so good as that from the cooks made here, but cost data were obtained which indicated that the use of either flax straw or tow was not economically feasible with ordinary paper-making materials at their present prices. A complete report is being published.

Barograph and Syphon Cable Paper (Curtis).

The study of the properties of special papers is best illustrated by the development of specifications for barograph paper and paper for syphon recording instruments for cable messages. In the former case the work was done at the request of the engineering division of the Air Service. A number of papers were examined, but it was necessary to study also the ink used under conditions that might be analogous to those found at high altitudes. Tentative specifications were finally developed and reported to the Air Service. In the case of syphon cable paper, however, the two factors that had to be con-

sidered were sizing quality and the surface of the paper. The instruments for recording the cable messages are so delicate and sensitive that the pen must easily make a mark with minimum resistance and the line should be clear to permit of easy reading of the message. Recommendations were made in regard to this type of paper.

Proposed Standard Substance for Paper (Curtis).

In connection with the general program on the standardization of paper, one of the committees cooperating with the bureau in this work has recommended the adoption of a standard substance or weight basis for all paper in place of the numerous bases now in use for the different grades or classes. This recommendation has been indorsed by a committee of manufacturers, by a committee of paper merchants, and by a number of organizations representing users of paper, printers, publishers, and purchasing agents. It has also been unanimously indorsed by a general conference held at the bureau in regard to the standardization of paper. A report advocating the use of this standard-weight basis was published in the Paper Trade Journal for August 17, 1922. It is believed to be a very necessary adjustment in order to have a common unit of weight that will eliminate confusion. The size recommended is 25 by 40 inches, or 1,000 square inches.

Technical Standardization (Curtis).

Considerable progress has been made in connection with the development of various phases of a suitable technical standardization of paper as to sampling, testing, and tolerances. The complete report of a committee appointed to consider this matter was published in the Paper Trade Journal for September 14, 1922, and was adopted with slight modification at a general conference held at the bureau. This report proposes standard methods of sampling paper, standard procedure for certain tests on paper, and also recommends definite tolerances. The report further indicates that no attempt has been made to prepare specifications of quality.

Sizes of Paper (Curtis).

For practically two years several committees have been cooperating on the problem of the sheet sizes of paper which could best be used in order to simplify and reduce the number of sizes made and kept on hand by the merchant. Careful surveys have been made by the committees, and the field covered includes paper sizes for general commercial printing, for books and magazines, for catalogues and directories, and for bond, writing, and ledger paper forms. The reports of the various committees were submitted to a general conference, composed of manufacturers, merchants, users, and other interested representatives or organizations for its action. All the reports were approved by the conference as a basis for further development and for adoption by the trade. These reports are to be published in detail, with sustaining data which were collected during the market surveys, which were made in each case.

Classification and Definitions of Paper (Curtis).

A systematic arrangement of the various kinds and types of paper into a classification for statistical purposes had been developed and has been approved by the general conference on paper standardiza-

tion. The types are arranged in 10 classes—absorbent, boards, building, cardboard, cover, news, printing, tissue, wrapping, and writing. These main classes are divided and subdivided in such a manner as to group together those papers that are characteristically alike and which are, in all cases, the primary product of paper mills and not converted products. In this classification there are about 175 main types, and the terms used are common in the trade. Definitions have been developed for these terms and are based on the classification. In a supplementary report the committee submits an additional list of approximately 800 terms with definitions based on the main types as given in the classification.

Case Lining Paper (Curtis).

In connection with an investigation and a manual being developed by the transportation division of the Bureau of Foreign and Domestic Commerce, a study is being made of the technical requirements of case-lining paper for overseas shipment. A number of representative samples have been obtained and were tested under normal conditions. Samples were also exposed to a temperature of 145° F. and were also frozen. Retests were made after the paper had been exposed. A number of samples were obtained from incoming foreign shipments and compared with domestic papers.

7. LIME, GYPSUM, AND SAND-LIME BRICK.

W. E. Emley.

Use of Hydrated Lime in Portland Cement Mortar (Johnson).

It is now quite customary to use a mixture of lime and cement in mixing mortar. The recommendations of different authorities run all the way from the addition of a little lime to cement mortar to the addition of a little cement to lime mortar, many city building codes specifying half-and-half. Obviously there should be one combination best adapted for a given purpose. This can be ascertained by measuring all of the important properties of all possible combinations. Both this bureau and numerous other investigators have been at work on this for some years. A new series of tests just completed included the measurement of plasticity, time of set, yield, shrinkage, and tensile strength of many different proportions of lime, cement, and sand. The report is now in preparation. The literature on this subject is so prolific that a bibliography is one of the important features of the report. The conclusions are drawn largely from the literature, using the bureau's data merely as supplementary. As a general proposition, it may be stated that a cement mortar leaner than 1:3 can be improved by the addition of lime.

Improvement of Plasticity of Hydrated Lime (Welch, Emley).

There are two kinds of hydrated lime for structural purposes, which are known to the trade as "masons'" and "finishing." The latter always commands the higher price, solely because of its greater plasticity. Last year the bureau succeeded in improving the plasticity of masons' hydrate to such an extent as to make good finishing hydrate. This process involved further treatment of the masons' hydrate, after manufacture. This year an endeavor has been made to improve the manufacturing process so that finishing hydrate,

rather than masons', will be the 'original product, and further treatment will be unnecessary. It seems that plasticity is dependent not only on the colloidal content of the hydrate, but the colloid, like glue, must be protected against drying out, especially at the temperatures normally reached in the manufacturing process, and it must also be prevented from flocculating itself when the mixing water is added preparatory to use. It has been found that the drying out can be prevented by letting the freshly made hydrate cool in an atmosphere of steam, and the flocculation by the addition of small amounts of a readily soluble calcium salt. A hydrator designed to apply these principles has just been completed for further experiment.

Use of Lime in Chemical Industries (Emley).

In some years, more lime is used in the chemical industries than in the building trades. Because it is the cheapest basic material, and also because of its great affinity for water, it is fundamentally important as a raw material in a large number of industries. Each industry, of course, has its particular needs, requiring a lime of certain properties. Public economy demands that any lime shall be used as far as may be for the purpose for which it is best adapted. The user wants to know what kinds of lime are available, and the maker wants to know what kinds of lime are needed. To answer these questions, the bureau has undertaken to prepare a series of specifications covering the different kinds of lime required by the larger users. To take advantage of the information possessed by other branches of the Government an Interdepartmental Conference on Chemical Lime has been organized to prepare these specifications, the chief of this section being secretary of this conference. Prior to publication, each specification is submitted for criticism to both makers and users of the particular kind of lime. Two of these specifications, covering the rag cooking (paper) and glass industries, have been published. Two more, for the causticizing and sulphite-pulp industries, are now in press. Water purification, ceramic whitening, silica brick, sand-lime brick, sugar, and leather are being studied.

Cause of Unsoundness of Lime Plasters (Emley).

Occasionally a type of failure known to the trade as "popping" develops in lime plaster. Small particles seem to expand and push themselves out of the plaster, leaving tiny holes. In extreme cases, these holes may be sufficiently large or numerous to be unsightly. An investigation made by the bureau some years ago indicated that popping could not be serious if the lime was all fine enough to pass a No. 50 sieve. Such fine material either would be completely hydrated during the mixing and application of the plaster, or the particles would be too small to leave noticeable holes if they did expand. It was therefore recommended that a requirement for this fineness be put in the specifications for lime. The manufacturers objected on the ground that certain impurities might be present in coarser sizes without causing trouble, and it would be unfair and unnecessary to grind such materials to the required fineness. To answer this question, the National Lime Association, the Contracting Plasterers Association, the International Plasterers Union, and this bureau cooperated in the erection of 98 panels of lime plaster. Different impurities were prepared in different sized particles and added to the lime. The

panels became one year old on March 4, 1923. An examination of them indicates that popping is caused by overburned lime or by lime burned during hydration. Other impurities, with the possible exception of sand, do not cause popping, regardless of their coarseness. The report has been released to the Journal of the American Ceramic Society, but is not yet published.

Investigation of the Physical Properties of Calcined Gypsum and Gypsum Products (Welch).

The results of previous work on this subject gave data on the properties possessed by most of the calcined gypsums and gypsum plasters on the market. In attempting to correlate these results, two subsidiary problems arose. Many gypsums contain small amounts of anhydrite, which is a form of calcium sulphate and could not be accurately distinguished from gypsum by chemical methods. This made it difficult to check the physical properties against the chemical composition. Most of the samples were either accelerated or retarded so that their most important property, time of set, was not normal. The effect of accelerators and retarders on both the time of set and the other properties had to be studied before the results could be safely interpreted.

A method has been devised for determining the amount of anhydrite in gypsum. It consists of dehydrating and then rehydrating the sample in a current of air of known humidity and temperature. During this process the anhydrite remains inert, and its amount can be calculated from the amounts of water lost and taken up. This report is now in preparation.

Lists of materials which accelerate or retard gypsum have been compiled from the literature, supplemented by the bureau's experiments. It has been found that, in general, the use of a retarder will cause a decrease in the strength of the gypsum.

Grading of Sand for Sand-Lime Brick (Johnson).

The important criteria for judging sand-lime brick are the compressive strength, transverse strength, and absorption. The product is classified by these three properties. Most sand-lime brick plants grind a part or all of the sand they use. It is then possible to control to some extent the fineness or grading of the sand. If this is done intelligently, it may improve the quality of the brick enough to raise its classification. We have previously published data on the effect of grading of sand on the absorption and transverse strength. A series of tests to show the effect on the compressive and tensile strengths have just been completed. In general, it seems that the finer the sand the better the brick. The report is now in preparation.

Improvement of Gypsum Block (Porter, Welch).

The present gypsum partition tile is designed to be used only for interior nonbearing partitions. There are no accepted specifications for the material. If the blocks can be improved in strength and weather resistance, they might find more extended use. The first step in the problem was to test all brands of block now on the market for compressive strength, transverse strength, absorption, rate of absorption, gypsum content, core volume, and expansion. This work

has just been completed, and the report will be used as a basis for specifications. Meanwhile, the value of various weatherproofing compounds has been investigated. The indications thus far are that treatment of the block with paraffin dissolved in a volatile carrier will increase its weather resistance.

Adhesion of Gypsum Plaster to Concrete (Porter).

Some difficulty has been experienced in making gypsum plaster adhere to a concrete wall. A series of preliminary experiments disproved the theory that this was due to chemical reaction between the gypsum and the cement. It was then assumed to be due to differential expansion between the two materials, gradually weakening and finally destroying the bond. Data on the expansion of concrete were already available. Tests were conducted to obtain similar data for gypsum plaster, especially as affected by the amount of sand in the plaster. It was found that the expansion of this material can be varied at will by use of a predetermined proportion of sand. By using such a proportion of sand that the plaster will have the same coefficient of expansion as the concrete, a good permanent bond can be obtained. For the usual type of concrete, the plaster should contain about two parts of sand to one of gypsum, by weight. The report will be published as an appendix to the annual report of committee C-11, A. S. T. M., for 1923.

How to Make Lime Set Quickly (Stockett).

When competing with gypsum, the slow setting of lime is sometimes a commercial handicap. By the addition of accelerators or retarders, the time of set of gypsum can be varied at will. It is desired to find some similar means to control the time of set of lime. It has been found that a mixture of ground quicklime and hydrated lime will set in the desired time, without undue change of volume. Unfortunately, this mixture will not keep well enough for commercial shipment. The bureau has, therefore, tried to devise a means to utilize it at the factory, by casting it in the form of partition tile. About the same time, the National Lime Association succeeded in making a similar block by extrusion from an augur machine, and without the use of the quick-setting mixture. Tests of these blocks show that they differ from the cast blocks to such an extent that there may be a market for both. The cast blocks are much lighter and more porous, and therefore better adapted for interior nonbearing partitions, while the extruded blocks are better for exterior bearing walls. Tests of the extruded blocks have been reported to the National Lime Association, but not yet published. The best mixture for the cast blocks has not been fully determined. It was found that a mixture of hydrated lime and unretarded Portland cement sets rather quickly, and this has been put on the market as a sort of quick-setting lime.

TESTING, INFORMATION, AND PUBLICATIONS.

Tests Completed During the Year.

During the year the following tests have been completed by the various sections of this division:

Steel-----	467	Concrete products-----	42
Iron-----	22	Testing sieves-----	124
Other metals and alloys-----	578	Building stones-----	106
Rope-----	58	Leather-----	191
Calibration of testing machines-----	2	Rubber-----	736
Large H columns-----	18	Textiles-----	5, 776
Structural members (Delaware River Bridge)-----	8	Paper-----	1, 636
Cement-----	5, 200	Lime and lime products-----	44
Concrete-----	811	Gypsum-----	12
Aggregates-----	58	Miscellaneous-----	536

Cooperation.

The following is a list of the more important societies and groups with which this division has cooperated during the past year. In the majority of cases the connection with these organizations has been through technical committees appointed by them to advise and consult with the bureau in regard to problems in which they are particularly interested.

American Concrete Institute.
 American Society for Testing Materials.
 American Society of Mechanical Engineers.
 American Bureau of Welding.
 National Research Council.
 American Engineering Standards Committee.
 National Advisory Committee for Aeronautics.
 American Society of Civil Engineers.
 American Association of Engineers.
 Engineering Foundation.
 Associated General Contractors.
 Joint Committee on Concrete and Reinforced Concrete.
 National Lime Association.
 Gypsum Industries Association (Inc.).
 Sand-Lime Brick Association.
 American Ceramic Association.
 American Zinc Institute.
 Cotton Thread Exchange.
 American Association of Woolen and Worsted Manufacturers.
 American Cotton Manufacturers Association.
 National Association of Cotton Manufacturers.
 National Association of Woolen and Worsted Spinners.
 National Association of Wool Manufacturers.
 National Association of Dyers and Spinners.
 National Electric Light Association.
 American Petroleum Institute.
 Society of Automotive Engineers.
 United Typothetæ of America.
 National Paper Trade Association.
 American Paper and Pulp Association.
 Technical Association of Paper and Pulp Industries.
 Association of National Advertisers.
 National Association of Purchasing Agents.
 Book Paper Manufacturing Association.
 Tanners' Council.
 Leather Belting Exchange.
 National Boot and Shoe Manufacturers Association.
 Rubber Association of America.
 Rubber Heel Club.
 American Leather Chemists' Association.
 Cordage Institute.
 Cotton Duck Association.
 National Association of Hosiery and Underwear Manufacturers.
 American Home Economics Association.
 Inter-State Cotton Seed Crushers' Association.
 National Association of Tent and Awning Manufacturers.
 Silk Association of America.
 Laundrymen's National Association.

Specifications.

The division has devoted considerable time during the past year to the development of specifications covering the purchase of materials for Government use. This has been carried on very largely through the Federal Specifications Board. Bearing in mind the fact that Federal specifications are very largely introduced into purchases by semipublic and private interests, particular attention has been paid to keeping in mind the viewpoint of the producer. Care has been taken not to demand a product which would entail undue hardship on the producer or the introduction of unusual practices. Specifications have been presented during the past year, and adopted by the Federal Specifications Board, for a large variety of rubber products including various types of hose, rubber tubing, jar rings, and packing. There are in course of preparation specifications for a variety of leather products, as sole, lace, upholstery, packing, and harness leather; various types of paper, as wrapping, blotting, mimeograph, toweling, carbon, chart, and ledger paper; wire rope; certain textile products, as duck and denims; and cementing materials, as Portland cement, natural cement, lime, and gypsum. The following have been issued by the Federal Specifications Board:

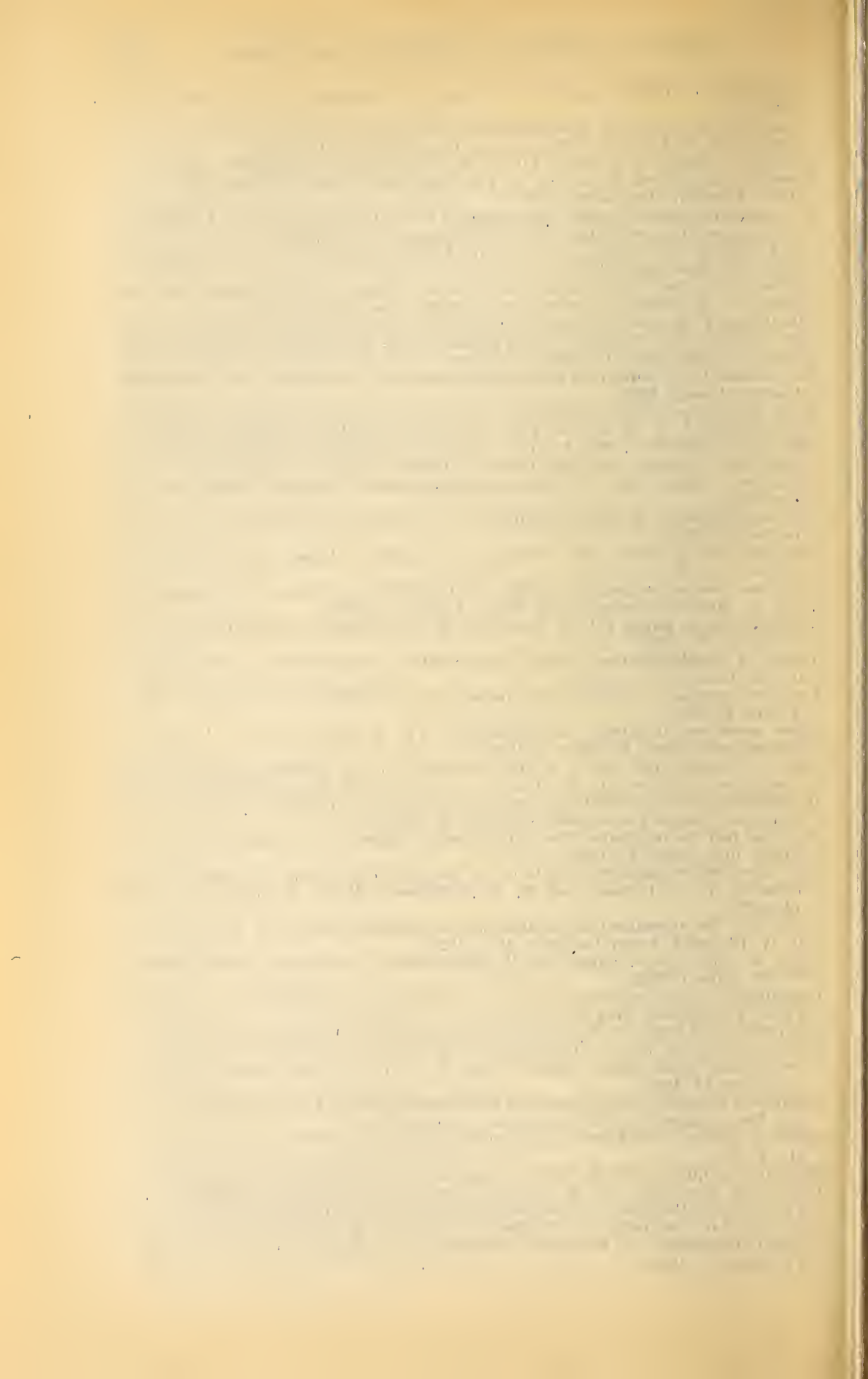
Pneumatic tires and inner tubes-----	F. S. B. No. 3.
Leather belting-----	F. S. B. No. 37.
Fire hose-----	F. S. B. No. 38.
Rubber tubing-----	F. S. B. No. 39.
Various types of hose, as gas, dredging, and suction--	F. S. B. Nos. 40-50, inclusive.
Jar rings-----	F. S. B. No. 51.
Numbered cotton duck-----	F. S. B. No. 53.
Test methods for rubber goods-----	F. S. B. No. 59.

PUBLICATIONS.

During the year the following reports of work done in the division have been published:

- Technologic Paper No. 218, Results of some compressive tests of structural steel angles (A. H. Stang and L. R. Strickenberg).
- Technologic Paper No. 229, Some tests of steel wire rope on sheaves (Edward Skillman).
- Technologic Paper No. 236, Loading test of a hollow tile and reinforced concrete floor of Arlington Building, Washington, D. C. (Louis J. Larson and Serge N. Petrenko).
- The effect of sudek treatment on the physical properties of several woods, Letter Circular 53.
- Calibration boxes for testing machines, Letter Circular 94.
- Bibliography on impact testing (H. L. Whittemore), Proc. Amer. Soc., for Test. Materials, 1922.
- Discussion on "Progressive failure of metals under repeated stress" (Moore, Kommers, and Jasper), L. B. Tuckerman, Proc. Amer. Soc. for Test. Materials, 1922, vol. 22.
- Notes on aerodynamic forces on airship hulls, National Advisory Committee for Aeronautics, Technical Note No. 129.
- Wide web column tests for Delaware River Bridge, editorial, Eng. News-Record, December 7, 1922.
- New developments in telemetric device (R. S. Johnston and O. S. Peters), Proc. Amer. Soc. for Test. Materials, 1923.
- Optical strain gauges and extensometers (L. E. Tuckerman), Proc. Amer. Soc. for Testing Materials, 1923.
- Technologic Paper No. 220, Test of a hollow tile and concrete floor slab reinforced in two directions (W. A. Slater, Arthur Hagener, and G. P. Anthes).
- Technologic Paper No. 233, Tests of heavily reinforced concrete slab beams (W. A. Slater and Fred B. Seely).
- Inspection of Portland cement (J. R. Dwyer and Roy N. Young), Concrete, August and September, 1922.

- Development of the flat slab (W. A. Slater), Philadelphia Record, March 30, 1923.
- Inundation methods for measurements of sand in making concrete (G. A. Smith and W. A. Slater), Proc., Amer. Concrete Inst., 19; 1923.
- Stresses in flanges of T beams (W. A. Slater), Concrete, November, 1922.
- Thoughts on concrete houses (J. C. Pearson), Proc., Amer. Concrete Inst., 19; 1923; Concrete, February, 1923.
- An interesting case of dangerous aggregate (J. C. Pearson and G. F. Loughlin), Proc., Amer. Concrete Inst., 19; 1923; Concrete, April, 1923.
- What quality of concrete block should become standard? (J. C. Pearson), Concrete, November, 1922.
- Discussion on the "Meaning and microscopic measurement of average particle size" (J. C. Pearson), Jour. Amer. Ceramic Soc., May, 1923.
- Alkali attack on concrete roads and building brick—A study of disintegration in Glenn County, Calif. (Irving Furlong), Eng. News-Record, July 13, 1922.
- Circular No. 135, Caustic magnesia cement.
- The possibility of improving hydraulic cements (P. H. Bates), Proc., Portland Cement Assoc.; 1923.
- What properties of and methods of making Portland cement require further investigation? (P. H. Bates), Proc., Amer. Soc. for Test. Materials; 1923.
- Technologic Paper No. 226, A study of commercial dial micrometers for measuring the thickness of paper (Paul L. Houston and D. R. Miller).
- Technologic Paper No. 217, The photomicrography of paper fibers (R. E. Lofton).
- The determination of sizing quality (F. T. Carson), Paper Trade Jour., September 7, 1922.
- Simplification of paper sizes (report of committee), Paper Trade Jour., November 9, 1923.
- Improvements in methods of making the Herzberg stain used in fiber analysis (M. F. Merritt), Paper Trade Jour., August 24, 1922.
- Rubber latex in paper (M. B. Shaw and G. W. Bicking), Paper Trade Jour., December 28, 1922.
- Technical standardization (report of committee), Paper Trade Jour., December 28, 1922.
- Proposed standard substances for paper (S. L. Willson), Paper Trade Jour., August 17, 1922.
- Paper research literature: A bibliography (F. A. Curtis and C. J. West), Paper Trade Jour., February 8, 1923.
- Effect of length and width of test specimen on the breaking strength and elongation of paper (P. L. Houston), Paper Trade Jour., March 22, 1923.
- Relationship between breaking strength and bursting strength of paper (P. L. Houston), Paper Trade Jour., February 8, 1923.
- A quick test to determine the brittleness of paper (P. L. Houston), Paper Trade Jour., April 12, 1923.
- The effect of atmospheric humidity in the physical testing of paper (P. L. Houston, F. T. Carson, and R. S. Kirkwood), Paper Trade Jour., April 12, 1923.
- A study of the experimental manufacture of condenser paper (M. B. Shaw and G. W. Bicking), Paper Industry, May, 1923.
- Aging of rubber latex paper (M. B. Shaw and F. T. Carson), India Rubber World, June 1, 1923.
- Classification and definitions of paper (report of committee), C. J. West, Paper Trade Jour., May 31, 1923.
- Manufacture of lime (W. E. Emley), Proc., Sand-Lime Brick Assoc.; 1922.
- Effect of hydrated lime on the strength and flow of concrete (W. E. Emley), Proc., Nat. Lime Assoc.; 1922; Proc., A. S. T. M.; 1922; Rock Products, November 18, 1922.
- Intelligent scientific control essential to the lime industry (W. E. Emley), Chem. and Met., August 30, 1922; Concrete; October, 1922.
- Tests of gypsum wall board and plaster board (J. M. Porter), Proc., A. S. T. M.; 1922.
- Standards of quality (W. E. Emley), Ingenieria Internacional, October, 1922.
- Bureau of Standards (W. E. Emley), Brazilian American, November, 1922; Proc., Amer. Chamber of Commerce of Sao Paulo, November, 1922.
- Department of Commerce (W. E. Emley), Brazilian American, November, 1922.
- General impressions of Brazilian business (W. E. Emley), Chem. and Met., February 14, 1923.



METALLURGY.

George K. Burgess.

FUNCTIONS.

The metallurgical division concerns itself with research, investigation, and testing as related to metals and alloys, except built-up metal structures and the processes of extraction of metals from their ores. Its functions include the production of metals and alloys, both of the highest attainable purity and of commercial grades; the preparation and study of auxiliary metallurgical products such as slags, included gases, molding sands, refractories, and deoxidizers; the development of apparatus, instruments, and manufacturing appliances for metallurgical processes, research, and testing; the formulation and maintenance of those standards and specifications of interest to metallurgists; the determination of metallurgical constants and properties; the investigation of the performance of manufacturing units; the determination of the causes of failure and the study of the improvement of metal products; and the development of economical metal substitutes. The division has equipment for metallographic examinations of metals such as microscopic analyses, including determinations of constitution, structure, and causes of failure; for thermal analyses, including determination of heating and cooling curves for location of critical points; for the various heat treatments, such as annealing, quenching, cementation, tempering; for various operations for the hot and cold working of metals, such as forging, rolling, and drawing, and for miscellaneous physical tests; for the usual foundry operations of molding and casting ferrous and nonferrous metals; and for other metallurgical processes, such as production of pure metals, electrodeposition and plating, welding, and determination of gases in metals.

SECTIONS.

1. Optical metallurgy.
2. Thermal metallurgy.
3. Mechanical metallurgy.
4. Chemical metallurgy.
5. Experimental foundry.

GENERAL STATISTICS.

Staff	43
Expenditures (1922-23)	\$84,000
Tests completed	4,181
Researches completed	37
Bureau publications	14
Other technical publications	44

WORK CHART.

I. OPTICAL METALLURGY.

SCOPE.

Identification of: (a) Metallographic constituents, (b) unknown alloys, (c) heat treatment, (d) mechanical history.

Constitution.

Causes of failure.

Etching reagents.

Metallographic apparatus.

Corrosion and its prevention.

Coated metals.

Metallographic standards.

Photomicrographs.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Iron and steel.....	87	186
Aluminum and aluminum alloys.....	34	13
Copper alloys.....	71	65
Coated metals.....	2	3
Platinum.....		8
Nickel.....	13	17
Cast iron.....	4	
Lead.....		3
Gold alloys.....		7
Tungsten.....		7
Miscellaneous.....	17	35

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Properties of carbon steels:			
Grain size and hardness.....		100	S397.
Grain size and other mechanical properties.....		15	
Tempering of hardened steel.....		100	S452.
Nonferrous corrosion:			
Lead.....		100	S377.
Copper (special phase).....		100	T158.
Soft metals, tin, aluminum, and zinc (special phase, intercrystalline attack).....		100	Outside. ¹
Comparison of test methods.....	A. S. T. M.....	5	
Etching reagents and methods:			
Copper.....		100	S399.
Copper alloys, nickel and its alloys.....		100	S435.
Aluminum.....		80	
Constituents of special steels.....		70	
Phosphorus and low carbon steels (microdistribution)	Steel manufacturer.	100	T203.
Electric arc welding:			
Characteristics of arc fused steel.....	American Welding Society.	100	T179.
Welded pressure tanks.....	American Welding Bureau.	100	Outside. ²
Nickel spark plug electrode.....		100	T143.
Structure of steel at high temperatures.....		100	S356

¹ Chem. and Met. Eng., 26, p. 109, 154, 212; 1922.

² American Welding Bureau No. 5, June, 1923.

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Defective steels (flakes).....	Army, Ordnance.	100	Outside. ³
Deep etching of iron and steel:			
Acid etching (concentrated acid).....		100	T156.
Persulphate etching.....		100	S402.
Microcharacteristics of wrought iron.....		100	T97.
Testing of galvanized materials.....	A. S. T. M.....	60	C80. Outside. ⁴
Ferrous corrosion:			
High chromium steels.....		75.	Outside. ⁵
Comparison of methods of tests.....	A. S. T. M.....	5	
Nick-bend test for wrought iron.....	Wrought iron manufacturers.	90	Do. ⁶
Properties of electrolytic copper.....		50	
Embrittlement of malleable iron in galvanizing.....	Malleable iron manufacturer.	100	

³ Trans. of American Institute of Mining Engineers, p. 246; 1920. American Railroad Association Report No. 85, November, 1919; Jour. of the Faraday Society, p. 110, 1921.

⁴ Proc. A. S. T. M., 17, p. 144; 1917.

⁵ Proc. A. S. T. M., 22, p. 193; 1922.

⁶ Am. Institute of Metals, 1916; Trans. Electrochemistry Society, p. 159, 1916; Trans. Electrochemistry Society, p. 103, 1923.

2. THERMAL METALLURGY.

SCOPE.

Thermal analysis: (a) Location of critical points, (b) survey of heat treatment, (c) new alloys.

Heat treatment: (a) Annealing and normalizing, (b) hardening and tempering, (c) cementation, (d) investigation of new alloys.

High temperature properties of metals.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Iron and steel.....	3,438	660
Nonferrous metals.....	72	73

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Steel at high temperatures:			
Boiler plate (tension).....	Various steel manufacturers.	100	T219. Outside. ¹
General carbon steels (tension).....		100	T205. Outside. ²
General carbon steels (compression and impact).....		30	
Alloy steels (compression and impact).....		30	
Alloy steels (tension).....		90	Do. ³
Heat treatment structural carbon and alloy steels:			
Nickel-steel properties.....		85	
1 per cent carbon steel.....		100	T206. Outside. ⁴

¹ Mining and Metallurgy, No. 158, sec. 15, February, 1920; Chem. and Met. Eng., 24, No. 3, p. 131, Jan. 19, 1921; Chem. and Met. Eng., 26, No. 26, p. 1207, June 28, 1922; Chem. and Met. Eng., 27, No. 5, p. 211, Aug. 2, 1922; Chem. and Met. Eng., 27, No. 7, p. 309, Aug. 16, 1922.

² Trans. Am. Soc. for Steel Treating, 2, No. 5, p. 409, February, 1922.

³ Trans. Am. Soc. for Steel Treating, 2, No. 5, p. 409, February, 1922; Iron Age, 110, No. 7, p. 404, Aug. 17, 1922.

⁴ Trans. Am. Soc. for Steel Treating, 2, No. 6, p. 467, March, 1922.

RESEARCHES—Continued.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Heat treatment structural carbon and alloy steels—			
Continued.			
High chromium (stainless) steel.....		100	Outside. ⁵
Molybdenum steels.....		100	Do. ⁶
High-speed steel:			
Performance lathe tools.....	Navy.....	75	T228. Outside. ⁷
Secondary hardness.....		100	S395. Outside. ⁸
Performance milling cutters.....	Navy.....	5	
Tool, die, and gauge steels:			
Artificial seasoning.....	Gauge committee, Army, Navy, and manufacturers. {	100	Outside. ⁹
Dimensional changes in hardening.....		25	
Study of gauge steel and their treatments.....		40	
Quenching media.....		25	
Melting points:			
Alloy steels.....		60	
Refractory cements.....		70	
Heat treatment duralumin.....		75	S347.
Pickling and heat treatment of rods, etc.....		100	Outside. ¹⁰
Apparatus for thermal analysis.....		95	T230, S348, 336.
Critical ranges of steels:			
Carbon steels.....		95	
Nickel steels.....		100	S376. Outside. ¹¹
Other alloy steels.....		60	S375. Outside. ¹²
Low-temperature critical ranges, iron and steel.....		40	
Iron-nitrogen diagram (new).....		15	
Hardened steels.....		100	S396. Outside. ¹³
Thermoelectric measurements.....		90	
Magnetic properties of steels:			
Eutectoid steel.....		100	S404, 408.
Permanent magnet.....		5	
Effect of surrounding atmospheres in heat treatment.....		65	
Gases v. heat treatment of steels.....		20	S457. Outside. ¹⁴

⁵ Jour. of Soc. of Auto. Eng., 7, No. 1, p. 103, July, 1920; Chem. & Met. Eng., 23, No. 1, July 7, 1920.⁶ Trans. Am. Soc. for Steel Treating, 2, No. 9, p. 769, June, 1922.⁷ Trans. Am. Soc. for Steel Treating, 2, No. 12, p. 1125, September, 1922.⁸ Trans. Am. Soc. for Steel Treating, 1, No. 9, p. 511, June, 1921.⁹ Chem. and Met. Eng., 25, No. 4, p. 155, July 27, 1921; American Machinist, 55, p. 768.¹⁰ Trans. Am. Electrochemical Soc., p. 543; 1920.¹¹ Mining and Metallurgy, No. 158, sec. 16, February, 1920.¹² Chem. and Met. Eng., 28, No. 5, p. 212, Jan. 31, 1923.¹³ Trans. Am. Soc. for Steel Treating, 1, No. 12, p. 212, Jan. 31, 1923.¹⁴ Trans. Am. Inst. of Min. and Met. Eng., 67, p. —, 1922.

3. MECHANICAL METALLURGY.

SCOPE.

Working of metals: (a) Forging, (b) rolling, (c) drawing, (d) welding, (e) soldering.

Railroad materials: (a) Cause of failure, (b) materials and specifications, (c) rails, wheels, axles, etc.

Miscellaneous properties: (a) Bearing metals, (b) fusible plugs, (c) miscellaneous tests, (d) specifications, (e) nomenclature.

Manufacturing appliances and processes.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Tin boiler plugs.....	446	456
Solders.....	7	4
Bearing metals.....	6	
Steels.....	5	
Saw blades.....	27	21
Miscellaneous.....	5	

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Bearing metals.....		70	T188.
Properties of A. S. T. M. bearing metals.....	A. S. T. M.....	100	Outside. ¹
Ratio of length to diameter in compression testing.....		50	Do. ²
Effect of impurities.....		20	
Graphitization of white cast iron.....	Car-wheel manufacturers.	90	T129.
Sulphur and phosphorus in steel.....	Joint Committee on Sulphur and Phosphorus in Steel.	15	Outside. ³
Properties of pure nickel.....	Nickel manufacturer.	40	
Light aluminum alloys.....		50	
Aluminum magnesium alloys.....		40	S363.
Solders for aluminum.....	Manufacturers..	90	C78.
Physical properties and constants of metals and alloys:			
Initial stresses in metals.....		40	
Volume change during solidification.....		5	
Properties of single crystals of metal.....		10	
Properties of antimony lead alloys.....		90	Outside. ⁴
High tin alloy constitution.....		90	
Failure of brasses and bronzes.....	Brass manufacturers.	80	
Railway materials:			
Temperature distribution in cooling metals.....		90	
Heat stresses in chilled iron car wheels.....	Car-wheel manufacturers. {	100	T209.
Heat stresses in steel car wheels.....		100	T235.
Effects of titanium in rail steel.....	Manufacturers..	100	
Properties of cast iron of the car wheel type.....	Car-wheel manufacturers.	20	
Working of metals (steel, brass, monel, etc.).....		Continuing.	T163.
Effect of conditions of hot rolling on properties.....		90	
Working of duralumin.....		15	
Working of 36 per cent nickel steel.....		10	
Effect of progressive cold drawing on properties.....		5	
Temperature measurements in metallurgical practice.....		50	
Resistance of metals to wear.....	Gauge-Steel Committee (in part).	20	

¹ Appendix to report of committee B-2, Proc. A. S. T. M. 1922.² Proc. A. S. T. M., June, 1923.³ Proc. A. S. T. M., 22; 1922.⁴ Chem. and Met. Eng. 25, No. 2, July 13, 1921.

4. CHEMICAL METALLURGY.

SCOPE.

Preparation of pure metals and alloys: (a) Influence of chemical composition on properties of metals, (b) development of new alloys, (c) working metals of high purity.

Study of gases in metals: (a) Development of methods of analysis, (b) influence of gases on physical properties, (c) deoxidation of metals, (d) solubility of gases in metals.

Study of metallurgical auxiliary materials: (a) Refractories, (b) slags, (c) ferro alloys and deoxidizers, (d) metal-melting furnaces.

Chemical metallurgy standards.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Steel.....	34	136
Nonferrous alloys.....	3	18

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Gases in metals.....	Various manu- facturers.	Continuing.	Outside. ¹
Method for oxygen and hydrogen.....		90	
Method for total nitrogen and steel.....		80	
Nitrogen as nitrides in steel.....		100	S457.
Oxygen in steel.....		50	
Oxygen in cast irons.....		30	
Nonferrous metals.....		30	
Decarburization of ferrochromium.....		100	S448.
Pure iron alloys:			
Fe-C, Fe-Mn, Fe-C-Mn, alloys.....		100	S453.
Sulphur in pure iron alloys.....		40	
Preparation and working of pure platinum metals.....		40	Outside. ²
Preparation of Pt Pt-Rh thermocouples.....		100	Do. ²
Special refractories for Pt melting.....		80	
Alloy for Brinell balls.....	Ball manufac- turers.	30	
Gases in alloy treated steels.....		20	
Relation of oxygen in steel to sulphur content.....	Joint Committee on S and P in steel.	10	
Special refractories for ferrous alloy melting.....		60	
Preparation and working of 36 per cent nickel steel (invar).....		80	
Caustic embrittlement of boiler plate.....	Boiler manufac- turer.	30	

¹ Proc. A. S. T. M.; 1923.² Trans. Am. Electrochemical Soc.; 1923.

5. EXPERIMENTAL FOUNDRY.

SCOPE.

Molding.

Casting: (a) Nonferrous metals and alloys, such as brass, bronze, aluminum, etc.; (b) steel and iron.

Molding sands.

New commercial alloys.

Foundry standards.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Castings:		
Brass.....	1, 213	1, 272
Aluminum and alloys.....	297	155
Lead.....	60	13
Bronzes.....	295	208
Zinc.....		7
Cast iron.....	28	374
Copper.....	13	161
Pb-Sb alloy.....	8	
Tin.....	15	6
Monel.....	2	
Nickel.....		268
Antimony.....		4
Babbitt.....		1

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Electric-furnace practice.....		15	Outside. ¹
Ferro alloys melting range.....		5	
Lead-zinc bronzes.....		100	
Art bronzes, patinas.....		82	
Molding sands:			
Recovery of steel sands.....	} Joint Committee (Am. Foundry- men's Assn., Nat'l Res. Council).	15	
Standards.....		45	
Testing methods.....		80	
Thermal conductivity.....		5	
Bond deterioration.....		5	
Improved zinc bronzes.....		85	
Impurities in bronzes and brasses.....		85	
Metal spraying process:			
Development of apparatus.....	} Army, Air Serv- ice; Navy. }	50	
Application of process.....		60	

¹ Bull. Amer. Inst. of Mining and Metallurgical Eng. Bulletin 51, 1919.

Detailed Report of the Year's Work.

GENERAL.

The appointment of the chief of the metallurgical division to the directorship of the bureau is the outstanding event of the past year. The general organization of the division, however, has not been greatly affected by this change.

The subject of "gases in metals" is receiving a great deal of attention from the division. The large number of requests for help and advice in this field received during the year is strong evidence of the need for and value of such an investigation, particularly in the iron and steel industry. The pioneer work of opening up the field and defining test methods has been practically completed and that phase of the work of more immediate interest to the industrial public, the correlation of the "gas content" of metals and alloys with their mechanical and other useful properties, has been well started. It is planned to continue the work as one of the major metallurgical investigations during the coming year.

The work of the joint committee on the study of the effects of sulphur and phosphorus in steel has been continued and extended during the year. The marked success of the "round-table" method used by this committee in its investigation of this very important and very much debated metallurgical subject has led to its adoption in several other cooperative investigations now being started. One specific instance which may be mentioned is the specifying of the quality of tin plate to meet the varied demands of the canning industry.

In the study of railway materials marked progress has been made. The publications summarizing the results of the investigation of the "braking stresses" in chilled iron and steel car wheels have been issued. The investigation of the comparative effects of different types of deoxidation treatment on rail steel has also been completed and the report is now in press.

A knowledge of the properties of metallic materials at elevated temperatures, particularly when the service of such materials involves these temperatures, is of very considerable industrial importance. Several printed reports containing the results of investigations of this kind were issued during the year.

The almost vital importance of gauges in modern manufacturing methods is well recognized. The gauge steel committee, organized for directing and conducting the study of suitable steels for this purpose and their proper treatment, has been very active during the year, and will be continued during the coming year.

In the work of the metals committee of the Federal Specifications Board the division has taken a very active part during the year, both the position of chairman and of technical secretary being filled by members of the division.

Decided progress in the testing of "noncorrodible" steels has been made during the year. The work will be continued and extended to other types of material for the purpose of developing standard corrosion testing methods.

Mention may be made of an investigation of the carburizing properties of steels now being outlined which was undertaken at the request of a group of metallurgists of the automobile industry and confirmed by a large number of commercial metallurgists canvassed for the expression of an opinion on the subject.

The number of unsolved problems in the fundamentals of physical metallurgy makes the extension of the methods of study beyond those now available at the bureau very desirable and necessary. Plans have been completed for applying X-ray diffraction methods to the solution of some of these problems and research along this line will be started and actively carried on during the coming year.

COOPERATIVE INVESTIGATIONS WITH TECHNICAL COMMITTEES.

Investigation of the Effect of Sulphur and Phosphorus in Steel.

The ultimate aim of the joint committee which is directing this research is the determination of suitable and safe limits for these two elements in various classes of steel. Up to date the question of the variations in sulphur has received most of the attention. The second annual report of the progress of the work which was presented before the American Society for Testing Materials summarized the results of tests made on steels of carbon contents of 0.2, 0.45, and 0.75 per cent carbon containing "added" sulphur of varying amounts. The first report dealt with steels containing "residual" sulphur. During the year the preparation of the various grades of plate steel containing various amounts of "residual" sulphur has been completed, and the testing is now in progress. The various forging steels, also illustrating the effects of "residual" sulphur, have been made and after heat treatment at the bureau will be sent to the laboratories of the Watertown Arsenal, Watertown, Mass., and the Naval Experiment Station, Annapolis, Md., where the testing will be conducted.

Some attention has been given to the relation between the percentage of oxide of the steels and their sulphur content. The results suggest a very striking difference, according to whether the sulphur is "added" or "residual." Further work is in progress for the pur-

pose of confirming the tentative conclusions already reached. Other laboratory work in progress relates to the results obtained by the evolution and the gravimetric methods for sulphur determination as carried out upon the steels of different carbon contents. A comparison of the sulphur content of steel containing "residual" sulphur after remelting with those containing "added" sulphur is also receiving consideration.

Welded Rail Joints.

This committee, the organization of which was mentioned in the last annual report, has made splendid progress in the carrying out of the investigation. The plans for the necessary circular experimental track which will be laid on the bureau grounds have been completed, and the construction will be started in the near future, the project being financed mainly by the American Electric Railway Association. The preparation of the various types of welded rail joints has been practically completed and some testing has been done. The committee has designed a special impact testing machine, which will be erected at the bureau for use in this investigation.

Mine-Drill Steel.

During the past year the joint advisory committee on this subject representing the Bureau of Mines, Bureau of Standards, and the industry completed the field survey on the general subject of mine drill breakage. Two reports on the subject were presented before the American Institute of Mining Engineers. In brief, it may be said that the survey showed that the subject of drill breakage was of less importance than it had been stated to be. The committee has in progress the preparation of a "Primer of heat treatment" as related to the subject of mine-drill steel. The future work contemplated includes the mathematical study of stresses in drills, the heat treatment of such steels, and the failure of drills as related to these two copies.

Molding Sand Investigation.

The study of molding sands which is being carried out in cooperation with the joint committee on this subject has shown a very decided dearth of reliable information along this line. The work taken up during the past year was confined to laboratory tests for the determination of the characteristic properties of these materials as related to their use in the foundry. Test methods for the measurement of the properties of fineness, permeability, and cohesiveness have been drawn up and released for criticism and suggestion through the American Foundrymen's Association. During the year this association, through its research committee, placed a research assistant at the bureau to aid in the laboratory work which is now under way.

Gauge Steels.

The military and industrial importance of gauges is unquestionably one of the most vital problems to be faced in manufacturing work. The investigation of this subject carried out in cooperation with the joint committee during the past year has been very successful.

Early in 1922 a committee representing gauge users, gauge manufacturers, steel makers, the Army and Navy ordnance departments, and the Bureau of Standards was organized for the purpose of con-

sidering means to improve the durability, permanence, and manufacture of steel gauges. Somewhat later an investigator was added to the staff of the bureau for full-time work on this problem. To this common cause the Army and Navy ordnance departments have contributed funds, several manufacturers have contributed steel, and others have machined test specimens. All of the experimental work is carried out at the bureau and five reports summarizing the results were issued to the committee during the past year.

In mapping out the program of work three principal phases of the problem were recognized, namely, the dimensional changes on hardening, the permanence of dimensions, and the resistance to wear. In regard to the first it has been shown that all tool steels increase in volume on hardening, so the problem is resolved into that of restricting the change to directions in which the least disadvantage is incurred. There are considerable differences in this respect between the several steels as observed in cylindrical specimens and expedients for the control of the changes are being studied.

The experimental work has shown that the changes with time are due in part to internal stress. Consequently it has been necessary to determine the magnitude and direction of the stresses in relation to the heat treatment. Some exploratory work in this field has just been completed. Subsidiary to this problem is that of the temperature distribution during heat treatment, which has led to an experimental and mathematical analysis of the temperature relations in bodies of simple shapes. The results are in the course of preparation for publication.

The investigation of the resistance of gauge steels to wear has served so far mainly to show the difficulties which must be overcome in this kind of testing and to aid somewhat in the general interpretation of the results of abrasion tests. This work is described later in more detail.

Corrosion.

The permanence of metals after fabrication is of great importance and second, perhaps, only in importance to the ability to prepare such metals in the first place. The desirability of instituting systematic research on the subject of corrosion has been strongly urged upon the bureau at different times. The bureau is represented on the corrosion committee organized by the National Research Council for the purpose of correlating investigations of this kind and also upon the two corrosion committees dealing with ferrous and non-ferrous metals of the American Society for Testing Materials. During the past year a great deal of attention was given to the corrosion testing of "noncorrodible" steels. This work is described later in another section.

Apparatus was constructed and used for the alternate immersion testing method, and during the coming year attention will be given to a comparison of the various common methods of corrosion testing, the same materials and solutions being used throughout all of the tests. The special apparatus for this is now in course of construction.

Federal Specifications Board Metals Committee.

The division of metallurgy has taken a very active part in the work of this committee during the year. Up to date 32 specifica-

tions, 18 relating to nonferrous metals and alloys and 14 to the ferrous group, have been completed by the committee and sent out for criticism. The bureau's advisory committee on nonferrous metals and the one on ferrous materials each devoted a large part of its meetings to a critical discussion of the specifications available. The value of suggestions of this kind from the leaders in the industries involved is an excellent proof of the service rendered by conferences of this kind.

Railway Materials.

During the past year the investigation on thermal stresses in car wheels was completed and the results published in the bureau's series of technologic papers. The comments which have been made by engineers upon the results of the analysis of stresses existing in a wheel operated under conditions approximating those of service indicate that they will be found very valuable by the railway designing engineer.

The laboratory study comparison of the deoxidizing effects of titanium and silicon upon the properties of rail steel has been completed and the results will shortly appear as a technologic paper. It is expected that the next investigation of railway materials to be taken up will be a study of certain types of service failure of rails to be investigated by a special joint committee on the subject.

Conferences.

Two well-attended meetings of the advisory committee on nonferrous alloys were held at the bureau during the year, at which were discussed the various current bureau investigations relating to those materials. Particular attention was given to the specifications for nonferrous alloys which had been completed and tentatively adopted by the metals committee of the Federal Specifications Board.

One meeting of the advisory committee on ferrous metals was held during the year, the discussion being along the same lines as given above.

A meeting of representatives of technical engineering societies, railway engineers, and others interested in the subject of rail failure was held at the bureau during June. At this conference plans were laid for a future meeting of a small working committee, at which a program for the cooperative study of certain types of rail failures will be considered.

The division cooperated in a conference called at the bureau for the purpose of considering suitable nondestructive tests for wire rope.

Arrangements have been completed for a conference to be held at the bureau early in the coming year at which will be discussed the subject of tin plate. Representatives of the National Cannery Association, the Can Manufacturers' Association, the tin-plate manufacturers, and the Bureau of Standards will attend this conference, which was arranged at the request of the cannery association. Attempts will be made to formulate suitable specifications covering the use of tin plate for the canning industry, a subject which concerns every user of canned foods.

The division through its chief, who acted as presiding officer, cooperated in a conference at the National Research Council of Makers and Users of Scientific Apparatus. The conference discussed subjects which are of immediate and very practical importance to the bureau, and a permanent organization to carry on the work was arranged.

Metallurgical Definitions.

The bureau cooperated with a special committee on definitions representing the American Society for Testing Materials, Society of Automotive Engineers, and the American Society for Steel Treating in formulating standard definitions of metallurgical terms used in heat treatment. The report will be referred to each of the three societies for discussion.

Circulars of Information.

The requests received by the bureau for reliable metallurgical information led to the preparation of a series of circulars dealing in a comprehensive and critical manner with the available information on typical metals and alloys. The number of requests for these publications would appear to justify fully their preparation. During the past year Circular 58, Invar and Related Nickel Steels, has been fully rewritten and is now in press. Circular 78, Aluminum Solders, has been brought up to date and reissued. Circular 100, Nickel and its Alloys, has been revised and verified and the revised edition will be published early in the year.

1. OPTICAL METALLURGY.

H. S. Rawdon.

General.

This term connotes the general method of investigation of metallurgical products involved. The metallographic microscope is one of the principal instruments and the extent to which it was used during the year is shown by the summary of the number of micrographs prepared; total, 1,848, of which 555 related to tests and 1,293 to investigations.

Etching Reagents for Alloy Steels (Grosbeck).

The metallographic etching of alloy steels with the usual acid reagents fails to identify the different constituents that may be present in the alloy steel such as the carbide of iron, chromium, tungsten, or vanadium, tungstite of iron, and possibly complex compounds as double carbides. This is of particular importance where two or more of the constituents are present simultaneously in the microstructure, as has been found to be the case with high-speed steels.

It was seen early in the investigation that, on the one hand, there was little hope offered by the use of the usual inorganic acids because of the general resistance of the above-mentioned constituents to the corrosive action of the acid; while, on the other hand, alkaline solutions of an oxidizing nature offered much of promise in producing distinctions by means of etching characteristics. A little experimental work was next carried out on various alkaline solutions with and without the use of oxygen gas or oxidizing agents, the

result of which work was the development of a new etching reagent, namely, a potassium permanganate and sodium hydroxide mixture.

With the object of establishing the identification of the metallographic constituent known or believed to be present in the microstructure by noting its behavior toward the various etching reagents, etching tests were made on various alloy steels with varying amounts of the alloying element and of carbon, using a number of etching reagents of an alkaline nature, among which were several well-known reagents as sodium picrate, Yatsevitch's reagent, etc. Heat tinting was also tried. The method of sequence etching, or etching with two or more etching reagents in succession without any repolishing of the specimen between the etchings, was used with success in cases where more than one constituent is present in the microsection, as in high-speed steels.

The results obtained so far have shown that it is possible by a proper selection of the etching reagent to determine in a satisfactory manner the presence or absence of the different constituents in the microsection and also to distinguish between several of the constituents when two or more are present in the same microsection, as, for example, cementite and chromium carbide, cementite and iron tungstide. No method has as yet been found for distinguishing between chromium carbide and tungsten carbide, other than from a consideration of the shape of the particles these constituents have been found to assume, should both occur in the same microsection.

Corrosion of Chromium Steels (Rawdon, Krynitsky, Bloxton).

The investigation of the corrodibility of different "noncorrodible" steels was continued throughout the year. The specimens, which represented a series of special steels prepared at the bureau, varied in carbon content from 0.06 to 1.44 per cent, and in chromium from 2.66 to 19.66 per cent. The methods of simple immersion and of repeated or alternate immersion were used, and a special apparatus for controlling the latter was designed and constructed. One publication of a preliminary nature was issued during the year.

The following general conclusions as to the corrodibility of this class of steels appear to be warranted by the results up to date:

(a) *Corrosion in distilled water.*—The composition and heat treatment rather than the character of the surface are the dominant factors determining corrosion resistance. The most resistant to corrosion in all cases were steels having 11.5 per cent or more of chromium and 0.40 per cent or less carbon. A relatively high carbon content lowers the corrosion resistance. Quenched (hardened) specimens withstood corrosion by the repeated immersion test much better than similar samples in the annealed state. Quenched specimens withstood corrosion much better when subjected to the alternate immersion test than in the simple immersion.

(b) *Corrosion in dilute hydrochloric acid.*—The resistance of annealed steels to corrosive attack decreases with an increase in the chromium content and similarly for carbon. In general, hardened samples show greater loss of weight than do annealed, but no regularity in behavior of the quenched specimen, according to composition, could be detected with certainty.

The work is being extended to other kinds of acids, citric being chosen as representative of fruit juices.

Corrosion of Metals by Alco-Gas (Rawdon, Lorentz, Sillers).

Unconfirmed reports concerning the corrosive action of certain mixtures of alcohol and gasoline used as motor fuels led to a request from the Bureau of Aeronautics, Navy Department, for a series of corrosion tests upon representative sheet metals and alloys. The first step in the investigation consisted in the determination of the ternary diagram (room temperature) of mutual solubility of the gasoline-alcohol-water system. The liquids chosen for the test were for the most part those found to consist of but one phase; that is, those lying within the range of composition of mutual solubility of the three. The gasoline used for the mixture was a high-test gasoline, such as is used for airplane-motor fuel. The sheets tested included the following: Uncoated iron and steel, tin plate, terneplate, galvanized steel, copper, brass, bronze, nickel brass, Monel metal, aluminum, and duralumin.

The investigation has not yet been completed, but the results obtained up to date indicate that the liquids used have very little effect upon most of the sheets (terneplate showing the greatest attack) and suggest that the inferior quality of gasoline used in such mixtures must be largely responsible for excessive corrosion if it occurs.

Crystallinity in Wrought Iron (Rawdon, Epstein).

This investigation, which is concerned primarily with the proper interpretation of the results of the nick-bend test usually included in the specifications for wrought iron, was mentioned in the last annual report. The work was extended during the year to include wrought-iron bars of large sections, wrought iron of very high phosphorus content, and open-hearth iron ("carbonless steel"). The work which has been practically completed leads to the following general conclusions: Crystalline areas appear most readily in the fractures obtained in the nick-bend test in those materials in which the individual slag threads are small and uniformly distributed. The presence of "steel" in wrought iron, being conducive to this condition, favors the formation of such crystalline areas. The converse is not true, however, for the presence of crystalline area is not a sure indication of the presence of steel.

The test can not be used as a means for detecting high phosphorus irons.

A rapid application of the load, usually by impact, is necessary for the formation of the crystalline areas. Distinction should be made between the crystalline areas on the tension and on the compression side of a bar. The latter are, in general, not to be regarded as indicative of the structural condition of the metal.

Inclusions in Steel (Epstein).

In the investigation previously referred to of the properties of rail steel after different types of deoxidation treatment, a good deal of attention was given to the study of the inclusions remaining in the steels after treatment. The physical nature, probable chemical composition of the inclusions, so far as it could be inferred from the available data, and distribution of the inclusions were studied. These features are discussed in a publication which is now in press.

Standard Grain Size for Condenser-Tube Brass (Rawdon, Sillers).

The attempt in specifications to control the properties of a metal by specifying the grain size which will be permitted is rather novel. In connection with the grain-size clause of the tentative specifications of the American Society for Testing Materials for condenser tube brass, a good deal of attention was given to the determination of grain size in this type of brass and the preparation of micrographs which would be representative of a structure of a given grain size. The results were submitted for inclusion in the new A. S. T. M. specifications for condenser-tube brass.

Microhardness (Sillers, Mutchler).

In cooperation with the committee on metallography of the American Society for Testing Materials a good deal of attention has been devoted to this subject. The usual methods for the determination of hardness do not give any indication of the variation in hardness of the metallographic constituents of which an alloy is built up. Such differences are readily indicated, however, by the variations in the width of the scratch or groove cut on a polished surface of such an alloy by an accurately ground "point" of some very hard material. Tests are being made to determine the accuracy of this method, the determination of hardness of a series of standards and some of the "practical" applications of the method.

Cold Working of Metals (Rawdon, Mutchler).

One of the applications which has been made of the microhardness method mentioned above is in the study of metals which have been subjected to very severe deformation by cold working. It is generally stated that the effect of such deformation is to harden progressively any metal, the hardness, in general, being proportional to the amount of deformation received. Some very striking exceptions to this general rule are indicated by the results already obtained. The hardness of many metals as measured by the "scratch hardness" and also by the microbrinell method increases rapidly during the early stages of cold deformation by rolling. A reversal occurs, however, and the metal becomes softer, so that in its final condition as a very thin sheet it is appreciably softer than in its initial state. This behavior has been found to hold true in the case of copper, iron, soft steel, and some of the nickel alloys. Some metals, however, such as aluminum, harden progressively as the cold deformation is increased. The results obtained indicate that some modification of the general theory which has been advanced as to the cause of hardness of metals by cold working may be necessary in order to explain satisfactorily the apparently anomalous behavior of some metals under these conditions.

**Crystalline Form of Electrodeposited Metals (Rawdon, Blum, Sil-
lers).**

The properties of metallic coatings deposited electrolytically are intimately related to the crystalline condition obtaining within such deposits. It has been shown during the past year in some preliminary work along this line that the crystalline structure of the base metal upon which an electrodeposit is made may, if properly cleaned prior to the deposition, predetermine absolutely the structure of the coating. Thus, of two coatings deposited under identical conditions

the one on a coarse-grained metal may be coarse, whereas that upon a fine-grained base of the same composition may be correspondingly fine. Contradictory statements have been made in the technical literature at various times concerning the possible effect of the base metal upon an electrodeposit laid down upon it, but these experiments, the results of which have been published, appear to be the first authoritative evidence on this point.

Considerable additional work leading to a generalization concerning the crystalline form of electrodeposits made under different conditions of deposition has been done, and the results will soon be published.

Structural Effect of Manganese in Carbon Steels (Rawdon).

This phase of the general investigation of the study of the iron carbon manganese alloys in progress in the metallurgical division was completed during the year, and the results published as a scientific paper. In brief, manganese confers upon an annealed steel a microstructure closely analogous to that which is obtainable in a similar steel, low in manganese, only by certain definite heat treatments. The shifting of the eutectoid ratio and the general lowering of the transformation temperature by the addition of manganese are accountable for most of the changes in structure observed.

Welded Pressure Tanks (Epstein).

A large number of metallographic examinations were made as part of the general investigation carried out by the bureau of a series of welded tanks prepared by the American Bureau of Welding. The results obtained, which are embodied in the published report of this work, did not appear to warrant including such a metallographic test as part of the general "acceptance clause" in specifications for this type of material.

New Investigations.

A line of metallographic investigation, to which it is planned to devote considerable attention during the coming year, is the study of the atomic structure of metals by means of X-ray diffraction methods. Work will be started as soon as the complete apparatus is received. It is believed that this study will aid very much in settling some of the obscure points in some of the investigations in progress at present, particularly the study of the effects of cold rolling of different metals, which will be continued and extended.

Requests from a number of metallurgists interested in the carburizing of steel products were received for an investigation along this line. The consensus of opinion of a large number of metallurgists canvassed on the subject was in favor of such an investigation. In this study, which will soon be started, emphasis will be laid upon the initial characteristics of the steel, the structural effects resulting after a standard carburizing treatment, and the results obtained after hardening the carburized steels. The cooperation of nearly all of the sections of the division will be necessary in carrying out this study. It is hoped that the investigation will throw light on the possible relationship between the initial quality of steel and the results obtained upon carburizing, concerning which there are very considerable differences of opinion at present.

2. THERMAL METALLURGY.

H. J. French.

Mechanical Properties of Metals at Elevated Temperatures (French, Tucker).

(a) *Tensile properties of steels.*—The high temperature tension tests of steels mentioned last year have been completed. More than 30 sets of tests were made at temperatures varying from room temperature to 600° C. (approximate) on the following steels: Normalized and quenched-and-tempered carbon steels of varying carbon contents; steels containing a single alloying element, such as nickel, chromium, tungsten, cobalt, manganese, or uranium; and commercial quaternary steels, such as chrome-nickel, chrome-vanadium, chrome-molybdenum, and nickel-uranium. From the standpoint of high ultimate tensile strength and limit of proportionality at high temperatures, the temperature scale for these steels may be divided into three parts: (1) The range 20 to about 450° C., (2) 450 to 600° C., and (3) above 600° C.

It was found in the lowest range that high strength and proportional limit are functions of composition and heat treatment, and, in general, combinations giving the highest strength at ordinary temperatures show similar superiority throughout the entire range. It is advisable, however, to keep carbon low, as brittleness increases rapidly with carbon content, particularly in the blue-heat range (300° C. approximate).

The upper limit in the second or "transition" range involves nearly full tempering of a hardened steel so that the benefits to be derived from heat treatment are limited except in the lower portion of the range, and high strength and limits of proportionality are largely functions of composition. Such elements as chromium, cobalt, uranium, molybdenum, and vanadium improve the strength, whereas nickel, even in large proportions, appears to soften the steel, particularly in the neighborhood of 550° C. and above.

It appears improbable that commercial steels can be produced to withstand continuously fairly large loads at temperatures above about 650° C., except when large proportions of one or more alloying elements are added to reduce the iron content to such low values that the resulting product can not correctly be called "steel."

(b) *Tensile tests of cast nickel-copper alloys.*—In addition to the above and with the cooperation of a commercial foundry, a study of the high temperature tensile properties of various nickel-copper alloys was undertaken. Several sets of tests have been carried out and the work will be continued.

(c) *Forging and compression tests.*—This investigation, which was mentioned in last year's report, has been modified and greatly extended. It includes comparison of various steels subjected to compression simulating the working in a press and impact as would be applied in a drop hammer at temperatures up to and including those at which steels are hot worked (1,000 to 1,200° C.).

Thus far comparisons have been made between carbon steels of different carbon content, carbon and 3½ per cent nickel rivet steels, and various structural alloy steels. Alloy-tool steels will also be included.

It has been found that the static loads required to produce definite deformations in carbon steels at 1,100° C. decrease with increase in carbon content, whereas in rapidly applied loads, as in forging, the reverse was found to be true. This means that high-carbon steel is harder to forge than low-carbon steel, but may be more easily deformed in a press. The differences between low carbon and 3½ per cent nickel rivet steels were found to be small.

High-Speed Steels (French, Diggs, and Strauss, of United States Naval Gun Factory).

In cooperation with the metallurgical and testing division of the United States Naval Gun Factory a large number of lathe tests of high-speed steels were made. The first part of this investigation, mentioned in 1922, has been completed and the report published as Technologic Paper No. 228. It may be characterized as a critical examination of the competitive breakdown test used of late in the purchase of high-speed steels, together with a preliminary survey of the compositions and properties of the current types produced. Such tests were found to be unsatisfactory as a basis of purchase, but may be used in cases where large differences in performance are expected, providing suitable precautions are observed. Thus this test may be used to detect steel of highly questionable quality. In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced, the performance of commercial low tungsten-high vanadium and cobalt steels was greatly superior to that of the high tungsten-low vanadium type and special steels containing small additions of uranium or molybdenum. However, these comparisons did not hold under more moderate working conditions.

Many of the tools tested were heat treated according to instructions furnished by the manufacturers, and it was noted that wide differences existed in recommended practice for steels of the same type composition which were to be subjected to the same service. In order to obtain more definite information regarding the heat treatment of high-speed steels a second investigation was begun and is now being completed. This included not only lathe-tool performance, but dimensional changes in hardening and consideration of "re-dressing" practices for tools.

Dimensional Changes in Hardening Steels (French, Cross).

Tests in this investigation were continued at intervals during the year and a study made of the effects on dimensional changes in hardening of such variables as initial properties and structure, rate of heating, and interrupted quenching. Various tool and die steels, including plain carbon, chrome-vanadium, tungsten finishing, chrome ball race, and high-speed steels were used. The construction of a dilatometer for measuring dimensional changes during rapid cooling (quenching) has been started. This work will be continued.

Study of Quenching Media (French, Berliner, Klopsch).

One of the new investigations recently undertaken, a study of technical quenching media, is of primary importance in the hardening of steels. Its purpose is to obtain more quantitative data than now exist concerning water, oils, brines, emulsions, etc., and will be

extended ultimately to include determination of temperature gradients during rapid cooling of relatively large masses.

Ordinary temperature-measuring devices are not suited for such work, so that it was necessary to set up and put into operating condition special quenching equipment and a string galvanometer. The preliminary work has been finished and a series of experiments with small samples completed so that within the next few months a preliminary report may be prepared.

Annealing of High-Carbon Steels (Klopsch).

Methods for rapid annealing (spheroidization) of high-carbon steels have received considerable attention during the past year, and a study has been made of the structure and properties of 1.10 per cent carbon steel as affected by several of the variables in annealing practice.

Nitrogen in Iron (Wymore, Cross).

Some attention has been given to the occurrence of nitrogen in iron. By the nitrification of pure iron samples in ammonia followed by a "diffusion anneal," it is hoped to obtain specimens which will give results by the thermal analysis method which can be used for constructing the iron-nitrogen equilibrium diagram. The results obtained on these specimens will be checked against those obtained by nitrification of iron dust in ammonia.

Thermoelectric Measurements of Critical Ranges in Pure Iron-Carbon Alloys (Berliner).

A study was completed by means of thermoelectric measurements of the critical ranges of pure iron carbon alloys containing from 0.07 to 1.5 per cent carbon. The decarburization of the higher carbon alloys, all of which were in the form of wire, was so severe that in many cases the results could not be used. In general, however, the results obtained were found to be consistent with previous determinations by other methods and showed conclusively that the A_2 transformation occurs at the same temperature, on heating and cooling, for alloys containing up to about 0.45 per cent carbon. It does not appear in alloys of higher carbon content as a separate and distinct energy change. A report is now in preparation.

Heat Treatment of Steels for Permanent Magnets (French, Hamill).

An investigation was recently started to determine the effects of varying heat treatment upon the steels now used commercially or suggested for use in the manufacture of permanent magnets.

Continued and New Investigations.

Much of the work now in progress is the result of specific requests from the industries or is being carried out in cooperation with technical organizations. Work will be continued in the study of high-speed steels, dimensional changes in hardening, quenching media, and the properties of metals at high temperatures.

In addition it is expected that one or more of the following investigations will be taken up during the year: (a) Artificial seasoning of cast irons, (b) effect of heat treatment on certain nonferrous light alloys, (c) effect of heat treatment on corrosion resistance of various steels, and (d) study of carburization of steels.

3. MECHANICAL METALLURGY.

J. R. Freeman, jr.

Bearing Metals (Freeman, Brandt).

The bureau has published the results of investigations on the mechanical properties in compression of white metal bearing alloys at normal and elevated temperatures. The size of the compression-test specimen used in these investigations conformed with the recommended practice of the American Society for Testing Materials with respect to the ratio of length to diameter of test specimen, which was 3 to 1.

In commercial laboratories a 1 to 1 ratio is generally used and reports have been published by other investigators giving the results of tests on specimens with still other ratios. Considerable discussion, therefore, developed regarding the intercomparability of results of tests made on specimens with different ratios of length to diameter. Accordingly an investigation has been completed during the past year on the influence of the ratio of length to diameter in the compression testing of babbitt metals. The results obtained showed that for loads up to and greater than those causing appreciable yielding of the alloy, the stress deformation curves in compression are identical for ratios of length to diameter of test specimens between 3 to 1 and 1 to 1 for specimens 1 inch in diameter. This is true for both lead base and tin base alloys.

At the request of committee B-2 of the A. S. T. M. a study is in progress of the effect of arsenic, iron, and copper on the mechanical properties of certain of their tentative standard white metal bearing alloys.

Car-Wheel Investigations (Burgess, Quick).

The investigation of thermal stresses in steel car wheels has been completed and results published as a technologic paper.

Cast Iron for Car Wheels (Freeman, Quick).

An investigation is in progress to determine the influence of sulphur, phosphorus, manganese, silicon, and total and combined carbon, respectively, on the properties of cast iron of the car-wheel type. Studies of the effect of nickel and chromium will also be made.

The iron is being prepared in crucibles and poured in the form of bars for the transverse bending test and chill test specimens. After determining the transverse strength, tension, and impact, test specimens are machined from the upper and lower portions of the broken transverse test bar. Tension and compression tests will also be made at elevated temperatures.

Wear Testing (Freeman, Rosenberg).

The study of the resistance of steels to wear, which was started last year, is being continued and is progressing satisfactorily. Tests are being made to determine the relative resistance to wear of commercial steels under different conditions of heat treatment when run in contact with steels of the same composition and heat treatment and of other compositions and treatment. It has been found that

with some steels the greatest resistance to wear is obtained by hardening, by quenching, and then tempering the steel at a low temperature, which tends to disprove the general belief that maximum hardness gives greatest resistance to wear. It has also been shown that the rate of wear is reduced very considerably by the removal of the fine abraded particles produced during a test.

Titanium Treated and Silicon Treated Rails (Burgess, Quick).

This investigation, previously mentioned, of the deoxidation effects of titanium and silicon on the properties of rail steel has been completed, and report submitted for publication as a technologic paper.

Invar Tapes and Shapes (Freeman, Neville).

The study of the forging and rolling characteristics of invar outlined in last year's report is being continued. Wire 0.004 inch in diameter has been successfully prepared, and ribbon 0.001 by 0.005 inch wide has also been made. Certain details of forging, however, are yet to be worked out, as many ingots split during forging.

Properties of Single Crystals of Metals (Freeman, Hromatko).

The study of the properties of single crystals is being continued, the crystals being prepared by the method mentioned in last year's report. Difficulty has been encountered in obtaining single crystals sufficiently large for determining satisfactorily their mechanical properties.

A knowledge of the characteristics of the single crystal is fundamental in any logical discussion of the properties of a metal as it exists in the form with which we are most familiar; that is, a conglomerate of numberless small crystals.

Miscellaneous.

Aside from the major investigations mentioned, this section is interested in the testing and development of aluminum solders, the volumetric changes in nonferrous alloys during freezing, the properties of lead-antimony alloys for use in storage-battery plates, and miscellaneous problems dealing with the mechanical working of metals and alloys.

The heavy mechanical working equipment, particularly the rolling mill and forging press, has been used extensively for the forging and rolling of special alloys for investigations by other sections, such as the rolling of special alloys for corrosion studies and the investigations in progress relative to the effect of sulphur and phosphorus in steel. A considerable amount of rolling has also been done for the Naval Gun Factory.

Proposed Investigations.

An investigation is contemplated to study the effect of progressive cold working, by drawing, on the mechanical properties of pure metals, in particular, the tensile properties. The drawbench is being fitted up for this work at the present time. The shape and characteristics of the stress-strain curve will be determined over the elastic range with an Ewing extensometer, and from the yield point to the ultimate strength with a Dalby optical load-extension recorder. This will give a complete and very precise measurement of the tensile curve from the "no load" to the "break."

4. CHEMICAL METALLURGY.

L. Jordan.

Preparation and Properties of Pure Iron Alloys (Neville).

The first scientific paper of a series having the above general title was published under the subtitle I, "Effects of carbon and manganese on the mechanical properties of pure iron," a summary being given in the annual report for last year. Sufficient material from the alloys made for this investigation was furnished the section of optical metallurgy and the section of magnetic measurements to permit investigations of the magnetic properties and the microstructure of these especially pure alloys. The results have been published as the second and third papers of this series.

Effects of Sulphur on the Properties of Pure Iron Alloys (Jordan, Neville).

The second phase of the work undertaken on pure iron alloys is concerned with the investigation of the effects of sulphur. Most of the alloys of this series have been fused in vacuum, electrolytic iron, pure carbon, manganese, and iron sulphide being used as the raw materials. Certain portions of the vacuum-fused series are duplicated by the preparation of ingots of as nearly as possible identical composition, but made by fusion with excess of air. The data from forging and rolling and from the mechanical properties of these alloys may be expected to point out the limits of sulphur causing red shortness in pure iron, the ratio of manganese to sulphur required to eliminate this red shortness, the effects of sulphur on mechanical properties, and the influence of the presence of oxygen or oxides in the metal on any or all of these properties. The investigation is thus closely related to the work being carried on by the Joint Committee on Phosphorus and Sulphur in Steel in its tests of commercial steels containing residual and added sulphur.

Investigations on the Platinum Metals (Jordan, Neville).

The investigations on the platinum metals are carried on in co-operation with the division of chemistry. The division of metallurgy is particularly concerned with the technique of melting and working the pure platinum metals and their alloys, the determination of the mechanical properties, and the study of selected alloys with respect to their suitability for platinum ware. Melting technique has necessitated the study of special refractories, thorium oxide, and to some extent zirconium oxide, being used at present. Methods of casting crucibles in plaster of Paris molds, previously used by this bureau in the manufacture of optical glass pots and other refractory shapes, have been successfully applied to the preparation of these thorium and zirconia crucibles. The bureau is cooperating with the manufacturers of high-frequency furnaces and producers of zirconia and thorium in the development of such cast crucibles of sizes adapted to commercial uses in precious metal melting.

Platinum-Platinum Rhodium Thermocouples (Neville).

As a part of the work on the platinum metals a thermoelement platinum and platinum-rhodium alloy superior in quality to the best material of this kind formerly in the bureau's possession has been

prepared. A large part of the rare metal thermocouples required by the bureau during the year have been made in its own laboratories.

Alloy for Balls for Brinell Hardness Test (Jordan, Neville).

A new alloy has been made which gives promise of being especially suitable for the manufacture of balls to be used in testing very hard steels. This material is a high-carbon vanadium iron alloy. It can be forged and by suitable treatment can be made extremely hard without, however, developing excessive brittleness. Further work on the development and testing of this alloy is in progress.

Special Alloys and Pure Metals (Neville).

As in previous years, there has again been a considerable demand made on this section for the preparation of special alloys, and of ingots, bars, and wire of vacuum-fused pure metals. The special facilities available for the production of high temperatures, either under atmospheric pressure or under vacuum, experience in the use of special refractories and in the smelting and working of metals of high purity have made possible the preparation of many special alloys which have been of great value in furthering a wide variety of investigations in many Government and university research laboratories.

Determination of Oxygen and Hydrogen in Metals (Jordan, Eckman, Barrows).

The development of the vacuum-fusion method for oxygen and hydrogen in metals has been brought to a very satisfactory stage. The method allows close check determinations on a given material, makes use of solid metal samples, thus avoiding errors through surface oxidation of chips, and completely determines all oxygen present in a metal as CO, CO₂, oxides of iron, manganese, silicon, and aluminum or any other oxides reducible by carbon or iron carbide at 1,500° C. in a vacuum. At present the vacuum-fusion method, involving the melting of the metal in contact with carbon, is the most generally applicable one for the correct determination of oxygen in both carbon-free and carbon-bearing metals.

Oxygen and Oxides in Steels (Jordan, Eckman, Barrows).

The vacuum-fusion method for oxygen has been applied to a number of steels for determining the efficiency of various methods of deoxidation. In such cases it has given information as to oxygen or oxide content of the steels which could not be obtained by any other method of analysis. One case which may be cited is the investigation of titanium-treated rail steels previously mentioned in this report. The bureau also applied this method of analysis to experimental heats of zirconium-treated steels prepared by a commercial research laboratory. The same method of analysis is being used in a study of a large number of commercial heats of open-hearth steels made under the supervision and for the work of the Joint Committee on Phosphorus and Sulphur in Steel.

Vacuum Fusion Method for Nitrogen in Metals (Jordan, Eckman).

Further progress may be reported on the method for determining nitrogen in metals by fusion in vacuum and absorption of nitrogen

in the evolved gases by metallic calcium vapors. Values for nitrogen in iron determined by this method are frequently lower than those obtained by the Allen method. The reasons for these differences have not been discovered as yet. Certain steels have given higher values by the fusion than by the solution method. Such results are to be expected, however, from the fact that the solution or Allen method determines only a part of the total nitrogen in many steels.

5. EXPERIMENTAL FOUNDRY.

C. M. Saeger, jr.

Production of Castings (Saeger, Flegel).

The number of requests received for special castings for use in the bureau's instrument shop, for the production of research material, and for use by several of the other Government departments has increased considerably over that of last year. During the past year 2,442 castings from 564 different patterns were made, an increase of more than 25 per cent over the number cast during the previous year.

New Foundry Equipment (Saeger).

Up to the present time the bureau has been handicapped somewhat by the lack of facilities for the production of cast iron. During the year a cupola to be used for this purpose has been installed. This will make possible the production of iron for casting purposes and also for refining into steel in the experimental electric steel furnaces, which form part of the equipment of the metallurgical division.

Molding Sands (Karr).

With the active cooperation of the joint committee on molding sands, the development of laboratory methods for testing these sands is receiving very considerable attention. Reference is made later to this work.

PROBLEMS OF MILITARY INTEREST.

Erosion of Steels for Machine-gun Barrels (Sveshnikoff).

In cooperation with the War Department, 25 alloy steels recommended for service as machine-gun barrels have been put through a series of physical and ballistic tests which are expected to disclose their suitability for ordnance purposes. The project, with its modifications and accessory investigations, is drawing to a close and should be concluded during the coming fiscal year.

Development of Light Armor Plate (Vanick, Herschman).

In conjunction with the War Department, the bureau has undertaken the problem of developing light armor plate and of preparing specifications expressing in physical terms those properties which are essential to the service of the plate.

The first portion of the problem allotted to the bureau has been completed, and reports of the work have been submitted to the War Department. Experimental data are being collected from the separate research units that have assisted in the work apart from the bureau, and the results are being condensed and interpreted into

tentative specifications. Meanwhile, experimental work is confined to investigations supplemental to the main research.

Development of Metals Resistant to Hot Ammonia Gases (Vanick).

The Fixed Nitrogen Research Laboratory of the Department of Agriculture has utilized the metallurgical facilities at the Bureau of Standards to assist in developing materials suitable for nitrogen-fixation apparatus which operates at high pressures and high temperatures in corrosive gases. Exposures varying from 2 to 12 months of a series of 50 ferrous and nonferrous metals and alloys have been completed in corrosion apparatus operated at their laboratories. The specimens are treated, tested, and microscopically examined at the bureau. The initial program is approximately 75 per cent complete, and satisfactory material for high pressure, high temperature fixation apparatus is assured from the results obtained.

Failures of metallic parts in service are examined for the purpose of adding to information relative to the precise conditions under which parts are in operation, thus guiding the selection of materials for the fixation apparatus. Service tests of fundamentally different commercial alloys are provided for with the same object in view.

Processes known as super-pressure processes have introduced new and more severe operating conditions which will demand new methods of experimental procedure to develop suitable materials for the accomplishment of such processes. No work under this activity has as yet been undertaken. The preparation of metallic base catalysts for the pressure-fixation processes present problems in the field of metallic oxide solutions to which such metallurgical tactics are applied as assist in the knowledge, study, and control of the oxide preparations.

RESEARCH ASSOCIATES.

The general subjects investigated during the year by the investigators placed at the bureau by various metallurgical companies were the same as those mentioned in the last annual report. In addition, a research assistant was added to the list by the National Foundrymen's Association to aid in the study of molding sands. The following is a general account of the accomplishments of these investigators:

Nickel Investigations (Waltenberg and Ruh, associate and assistant).

Investigations which have been in progress during the past year include the following: Intercrystalline deterioration of nickel; equilibria of nickel-nickel oxide; effect of common impurities on the malleability of nickel and Monel metal.

The research division of the International Nickel Co. is cooperating with various sections of the bureau in the following investigations: Nickel compounds as fillers in rubber, nickel and Monel metal deposits obtained with a metal-spray gun, efficiency of different types of nickel anodes in electroplating, and preparation of pure nickel.

No publications of any work were issued during the past year.

Intercrystalline Deterioration of Nickel.

A comparison was made of the intercrystalline deterioration of low manganese nickel, grade "A," and high manganese nickel, grade "D," when heated for a period of four hours at 1,100° C. in contact

with ferric oxide or silica and in the presence of carbon dioxide or sulphur dioxide. The high manganese or grade "D" nickel deteriorated less in every case. The presence of sulphur dioxide was found to accelerate greatly this type of deterioration.

Equilibrium of the Nickel-Nickel Oxide System.

Nickel oxide when present in nickel occurs as the compound represented by NiO . It is practically insoluble in solid nickel and forms a eutectic with nickel at 1.1 per cent NiO , (0.24 per cent O_2), the melting point of the eutectic being $1,438^\circ \text{C}$. The melting point of NiO was found to be $1,660^\circ \text{C}$.

Effect of Common Impurities on the Malleability of Nickel and Monel Metal.

It is believed the results of this investigation show conclusively that sulphur is the only element usually found in nickel which causes it to be nonmalleable, and sulphur above 0.01 per cent causes nickel to be unsuitable for hot forging. This applies to nickel to which no manganese has been added; the addition of manganese changes the sulphur constituent to a manganese sulphide and improves the forging properties; the addition of manganese 0.1 per cent changes the sulphur constituent to a magnesium sulphide and produces malleable nickel, with or without the presence of manganese.

Open-Hearth Iron Investigation (Cain, associate).

The investigations for the past year have dealt mainly with the following subjects: Additional tests have been made on various refractory mixtures for stopper-sleeve brick. No entirely satisfactory mixtures have been found, partly because of lack of uniformity of some of the raw materials tried and partly because of price fluctuations of the latter.

Further investigation has been made of the manganese-sulphur ratio necessary to prevent red shortness of low-carbon ferrous products. The indications are that further research may be necessary before publication of the results. From what has been ascertained thus far it would seem that there are many cases where the prevention of the red shortness is not merely a question of the ratio of manganese to sulphur, but that other considerations of unknown nature also enter. Additional melts have been made to test the effect of high-oxygen content on red shortness in the practical absence of sulphur, and the conclusions previously reached are sustained by these tests.

The preparation of specimens for a study of thermal critical points of low-carbon ferrous products has been completed. These specimens have been analyzed, and the study on the thermal transformations is soon to be started.

Several modifications in the design of apparatus for determining gases in metals have been made. One apparatus is for the study of gases in low-carbon iron by a modification of the Goeren's method, and it may also be used for the analysis of some specially deoxidized materials. A modification of the vacuum-induction furnace to be used in deoxidation studies has been completed. This furnace has been tested and found very satisfactory for the work intended.

The preparation in the special induction furnace of a series of pure iron melts under controlled amounts of air has been started. This investigation is intended to yield information as to the rate of oxida-

tion of iron and the absorption or retention of the iron oxide formed. This information, in turn, will guide in the preparation of iron with definite or known oxide content as a "standard" material against which to test deoxidizers.

Galvanizing and Brass Foundry Problems (Marshall, associate).

The investigator working on this line of research completed his work at the bureau at the middle of the past year. The results of the investigation on the embrittlement of malleable cast iron during galvanizing will soon be published in the bureau's series of technologic papers. Following is a summary of this work:

Recent investigations have shown that commercial malleable iron is often embrittled as a result of galvanizing by the "hot-dipping" method. The present study, however, has shown that this change results from quenching from certain temperatures in the blue-heat range and that the galvanizing plays no other part than the means of heating the iron. The low-shock resistance of such material after hot-dip galvanizing is often very striking. The present study of the problem showed that the magnitude of this deterioration varied with different samples of iron. The Izod impact test was used as a convenient means for measuring the resilience of the metal. The embrittlement was found to be limited to a fairly definite range of quenching temperatures. Aging after treatment did not appear to affect the results. The rate of cooling from the blue-heat range was important, however. If the malleable iron was slowly cooled instead of quenched from these temperatures, the impact resistance was not nearly so seriously impaired. It was also found that the upper limit of the "embrittlement zone" lay a few hundred degrees (C.) below the critical point. Quenching from temperatures in this upper safety zone increased the resilience of the iron and made it immune to the blue-heat deterioration. The information obtained did not solve the question of the fundamental cause of the embrittlement, but did point out a convenient and simple method for eliminating it.

Molding Sand Investigation (Aungst, assistant).

During the year an assistant was placed at the bureau by the American Foundrymen's Association to aid in the testing and study of molding sands. The work is carried out under the supervision of the section chief and most of the time up to date has been spent in testing the methods tentatively adopted by the Joint Committee on Molding Sands for the testing of such materials. These include the test for fineness by the sieve test, the determination of cohesiveness or bond strength by the overhanging bar method, and the measurement of the permeability by the rate of flow of a standard volume of air through the sand under standard conditions. The committee plans to test all sands submitted by the State geologists of the different States that show any promise of being utilized as molding sands, and these are three of the important tests which are to be made on all sands. Two of the States have already submitted samples which have been tested.

TESTS.

The following cases are given as typical of examinations of this kind which the division has been asked to make during the past year. Many of the examinations made by the division and listed as

tests are largely investigational in character. They are of great variety, and each requires individual treatment.

Corroded Material.

The following are listed as typical of the variety of corroded products this division is called upon to investigate. In cases of this kind an opinion is usually requested as to a more satisfactory material to use.

(a) A number of luminous buoy lights used on shipboard failed, one exploding on deck. These "water" lights consist of a sheet-metal can containing calcium carbide and calcium phosphide, which ignite by the action of the water when the can is thrown overboard. The corrosion of the container because of electrolytic action was most severe underneath the brass labels attached to the cans giving the manufacturer's name. It was recommended that the cans should be of copper and that the use of metallic labels or tags should be strictly forbidden on this class of material.

(b) The rivets of part of a duralumin girder from a wrecked dirigible were found to be very severely corroded, the deterioration being so severe that they could be easily cut with a knife. The duralumin strips also showed evidence of corrosion by intercrystalline embrittlement. It could not be learned whether the corrosion took place while immersed in sea water or in the air. Chemical analysis showed the rivets to be much lower in alloying elements than is the regular duralumin.

(c) A portion of copper boat sheathing had so rapidly deteriorated in service that in less than a year it had a lace-like appearance. The oxide content was slightly greater than that usually found in commercial sheet copper, but otherwise the material appeared to be of high grade. It was concluded, therefore, that the failure was due to some unusual service condition rather than to any defect or abnormality in the metal.

Tungsten Lamp Filaments.

A number of tungsten lamp filaments which varied considerably in performance were examined. Particular attention was given to the changes in structure which occur as the lamps are burned and the filaments deteriorate, in the endeavor to show why some lamps have an abnormally short life. The expenditure of considerable effort on the technique of polishing and etching the fine wires was required. It was possible from the metallographic examination to point out some defects and the probable sources of weakness.

Tool Steel Graphitization.

Attention was called in one of the technical journals to a rather unusual condition sometimes found in carbon tool steels which cause them to have a black-heart fracture. No satisfactory explanation of the phenomenon being advanced, a specimen of this material was secured and examined at the bureau. Microscopic examination showed that an almost complete graphitization of the cementite in the central portions of the rolled bars was responsible for the peculiar appearance of the fracture. The characteristic shape of the graphitic portion of the bar suggested strongly that some condition originating in the ingot was responsible for the relative ease of graphitization upon annealing. The ordinary chemical analysis, however, showed no essential differences in chemical composition

along the cross-sectional zones of the bar and hence did not indicate what this condition might be. Manufacturers of steels of this kind have found, as a result of experience, that the presence of a very small amount of chromium will prevent graphitization upon annealing.

Deterioration of Steel by Brazing.

A "wire-pull" terminal of medium carbon steel developed cracks after brazing. The microscopic examination showed that as a result of the high brazing temperature used, the copper brazing alloy had penetrated into the steel in an intergranular manner, causing intercrystalline brittleness of the steel. It could not be ascertained whether or not the steel part was under stress while being brazed. Such a condition, if it did obtain, would contribute to the attack of the steel by the molten brazing metal.

Defective Lead Cable Sheathing.

The sheathing was defective by reason of a number of small transverse cracks which had permitted the infiltration of water. The examination showed nothing which suggested inferiority of the material. The indications were that the cracks had originated at some stage in the manufacturing process, while the lead was at a rather high temperature.

Platinum Gauze Catalyzer.

A portion of a platinum gauze cylinder used as a catalyzer in the oxidation of ammonia had become very weak and brittle in service. The microscopic examination showed that the wires had become very much roughened and notched so that the surface of the wires was very much increased. This is common in platinum after being used for this purpose, and apparently is a necessary accompaniment of the "activation" process. The chemical conditions under which the gauze was used also might have contributed to the weakening of the wires.

"Aluminized" Steel Tie Bolts.

The bolts were to be used in furnace construction and were therefore to be exposed to elevated temperatures. The "aluminizing" apparently had been done by the immersion of the bolts in molten aluminum. A noticeable alloy coating had formed by the penetration of the aluminum into the iron. The coating was not comparable, however, with that formed in the commercial process of "calorizing" and it did not seem that for severe high temperature service the "aluminized" bolts would "stand up" better than bare steel.

Special Process of Heat Treatment of Tubes.

In this process, so far applied largely in an experimental manner for the heat treatment of thin-wall tubes, the metal is heated by its resistance to the passage of electric current. An investigation of this method of treatment for brass condenser tubes was carried out at both the plant of the manufacturer and the bureau, and a report covering the application and limitations of the process was prepared.

Miscellaneous.

The following materials may be mentioned as illustrative of the wide variety of materials the division is called upon to examine: Solder and soldering paste, aluminum solder, aluminum kitchen uten-

sils, dental burs, failed bearing, failed carburized steel-driving pinion, automobile tire chains, copper-lead graphite commutator brush, ball pein machinist's hammer, broken drive shaft from auto-truck, graphitic bearing metals, inferior hypodermic needles, lead-coated steel sheets and wire, exploded boiler tubes, die steels, air furnace and electric furnace cast iron, nickel of varying sulphur content, silver coinage alloys, welding rods, brass condenser tubes, electrical fuse wires, alloys for steam turbine buckets, "gas content" of copper, zinc, malleable cast iron, Monel metal, and steels.

Fusible Plugs.

There were 456 fusible boiler plugs tested for the Steamboat Inspection Service. Of these, 260 met satisfactorily all the requirements of the specifications; of the remainder, 12 were reported as having loose fillings and 184 were rejected; of these, 62 had a copper content more than 0.3 per cent; in 13, the lead content exceeded 0.1 per cent; 18 had a copper content more than 0.3 per cent and lead in excess of 0.1 per cent; 3 showed the copper content to be more than 0.3 per cent and the iron more than 0.1 per cent; in 74, the total impurity was more than 0.3 per cent; 4 were inferior, as the melting point was less than 230° C.; in 9, the tin fillings were loose; and 1 had a casing which was not bronze.

Summary of Tests.

The table below gives a summary of the more important tests completed by the division during the year, the estimated value of which is \$12,870. For a complete statement of all tests completed, the table at the beginning of the report of this division should be consulted.

CERTAIN OF THE MORE IMPORTANT TESTS COMPLETED DURING THE FISCAL YEAR 1922-23.¹

	Heat treatment, thermal analysis and high-temperature mechanical tests.		Metallographic (including physical and corrosion tests.		Chemical metallurgy, gas content in metals.		Fusible plugs.	Castings.		Total.
	Iron and steel.	Non-ferrous.	Iron and steel.	Non-ferrous.	Iron and steel.	Non-ferrous.		Iron and steel.	Non-ferrous.	
For the Government:										
Agriculture Department.....				1						1
Bureau of Standards.....	640	3	124	81	49	3		112	1,351	2,363
Navy Department.....			2		2			5		9
Panama Canal.....			4	2						6
Steamboat Inspection Service.....							456			456
War Department.....	6		15	10						31
Treasury Department.....	8		2	2	1					13
U. S. Shipping Board.....	2	6	16	45						69
Post Office.....			3	2						5
Coast and Geodetic Survey.....									519	519
General Supply Committee.....			21							21
Inter-state Commerce Commission.....			1							1
Government Printing Office.....			5							5
Department of Commerce.....			4	1						5
Veterans' Bureau.....			4	4						8
Total.....	656	9	201	148	52	3	456	117	1,870	3,512
For the public.....	4	64	15	18	14	2		15		132
Grand total.....	660	73	216	166	66	5	456	132	1,870	3,644

¹ For detailed statement arranged according to sections of the Metallurgical Division, see tables on pages 218 to 251.

PUBLICATIONS.

Publications by members of the metallurgical staff relating to the work of the division appearing during the year are as follows:

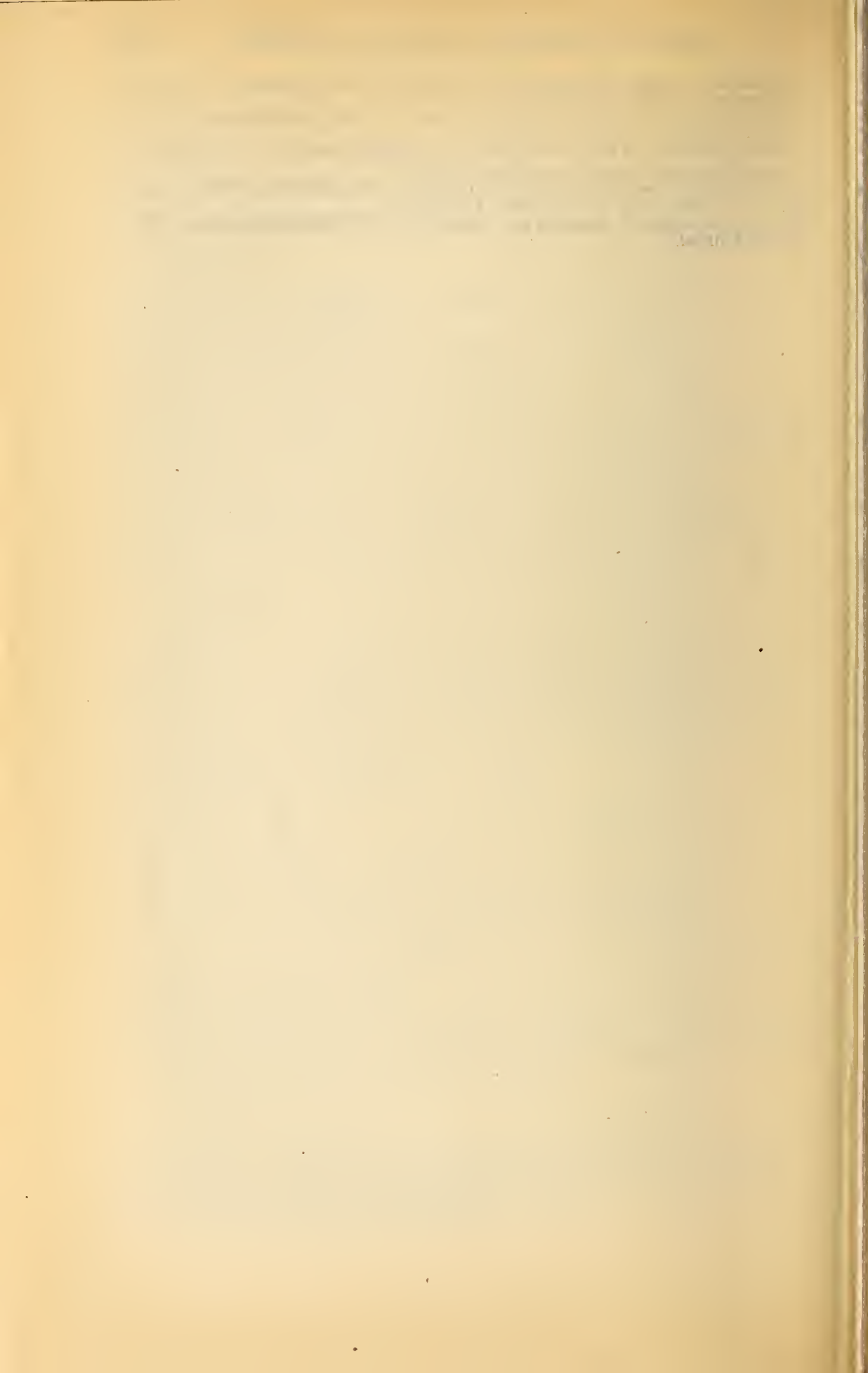
- Thermal stresses in steel car wheels (G. K. Burgess and G. W. Quick), Tech. Paper 235; also *Railway Age*, 74, p. 951; 1923.
- The study of steels for engineering structures (G. K. Burgess), *Proc. Am. Soc. Civ. Engrs.*, 49, pp. 524-547; 1923.
- Annual table of constants, preface to section on engineering and metallurgy (G. K. Burgess); 1922.
- Dr. S. W. Stratton (G. K. Burgess), *Technology Eng. News*, 3, p. 146; 1922.
- Standardization and research (G. K. Burgess), *Amer. Mining Cong.*; November, 1922.
- Contribution to discussion of corrosion of ferrous materials (G. K. Burgess), *Proc. British Inst. Civ. Engrs.*, 214, Pt. II, p. 183; 1922.
- Presidential address, The trend of standardization (G. K. Burgess), *Am. Soc. for Test. Materials*; June meeting, 1923.
- Second preliminary report, joint committee on investigation of sulphur and phosphorus in steel (G. K. Burgess and C. L. Warwick), *Proc. A. S. T. M.*; June, 1923.
- Structure and related properties of metals (H. S. Rawdon), *Trans. Am. Soc. Steel Treat.*, 3, pp. 649-679; 1923.
- The influence of the base metal on the structure of electrodeposits (W. Blum and H. S. Rawdon), *Trans. Am. Electrochem. Soc.*, 43; May meeting, 1923.
- Graphitization of a carbon tool steel (H. S. Rawdon and S. Epstein), *Chem. and Met. Eng.*, 27, p. 650; 1922.
- Preparation and properties of pure iron alloys: The effect of manganese on the structure of alloys of the iron-carbon system (H. S. Rawdon and F. Sillers, jr.), *Sci. Paper* 464; also *The Iron Age*, 110, pp. 1357-1361; 1922.
- Copper, Circular 73 (revised) (H. S. Rawdon and M. G. Lorentz).
- Protective metallic coatings for the rust proofing of iron and steel, Circular 80 (revised) (H. S. Rawdon).
- The structure of martensitic carbon steels and the changes which occur upon tempering (H. S. Rawdon and S. Epstein), *Sci. Paper* 452.
- Resistance to corrosion of various types of chromium steels (H. S. Rawdon and A. I. Krynitsky), *Chem. and Met. Eng.*, 27, p. 171; 1922.
- Contributory factors in corrosion (H. S. Rawdon), contribution to discussion of preliminary notes on corrosion, *Proc. Am. Soc. Test. Mat.*, 22, pt. 1, p. 238; 1922.
- Deterioration of alloys by internal oxidation, contribution (H. S. Rawdon) to discussion of The oxidation and swelling of zinc-aluminum alloys, *Am. Inst. Min. and Met. Eng.*, pamphlet 1190; 1922.
- Some metallographic features of manganese bronze, contribution to discussion (H. S. Rawdon) of The blue constituent in high-strength manganese bronze, *Am. Inst. Min. and Met. Eng.*, pamphlet 1190; 1922.
- The scratch-hardness method, contribution (H. S. Rawdon) to discussion of A study of bearing metals, *Trans. Am. Inst. Min. and Met. Eng.*, February meeting, 1923.
- The microscopic examination of "dirty" steel (S. Epstein), *Chem. and Met. Eng.*, 28, p. 482; 1923.
- A recording chronograph for the inverse-rate method of thermal analysis (H. J. French), *Tech. Paper* 230; also *Trans. Am. Soc. Steel Treating*, 3, p. 640; 1923.
- Effect of temperature, deformation, and rate of loading on the tensile properties of low-carbon steels below the thermal critical range (H. J. French), *Tech. Paper* 219.
- Strength and elasticity of boiler plate at elevated temperatures (H. J. French), *Chem. and Met. Eng.*, 26, No. 26, p. 1207; 1922.
- Boiler plate after cold-work or work at blue heat (H. J. French), *Chem. and Met. Eng.*, 27, No. 5, p. 211; 1922.
- Effect of rate of loading on tensile properties of boiler plate (H. J. French), *Chem. and Met. Eng.*, 27, No. 7, p. 309; 1922.

- Effect of temperature, deformation, and rate of loading on the tensile properties of low-carbon steel below the thermal critical range (H. J. French), Tech. Paper 219.
- Note on the strength of stainless steel at high temperatures (H. J. French), *The Iron Age*, 110, p. 404; 1922.
- Lathe break-down tests of some modern high-speed steels (H. J. French and J. Strauss, U. S. Naval Gun Factory), Tech. Paper 228; also *Trans. Am. Soc. Steel Treat.*, 2, p. 1125; 1922.
- The constitution of the alloys of iron and nickel (D. Hanson (National Physical Lab.) and J. R. Freeman, jr.), *Jour. Iron and Steel Inst.*, 107; May meeting, 1923.
- The influence of ratio of length to diameter in the compression testing of ball-bitt metals (J. R. Freeman, jr. and Paul F. Brandt), *Proc. Am. Soc. Test. Mat.*; June meeting, 1923.
- Solders for aluminum, Circular 78 (revised) (J. S. Hrenatko).
- Contribution to discussion of white-metal alloys (J. R. Freeman, jr.), *Jour. Inst. of Metals*, 28, 174; 1922.
- On precision altimeter design (J. R. Freeman, jr. and J. B. Peterson), Report 126, National Advisory Committee for Aeronautics; 1922.
- The physical properties of the A. S. T. M. tentative standard white-metal bearing-alloys (J. R. Freeman, jr.), *Proc. Am. Soc. Test. Mat.*, pt. 1, p. 207; 1922.
- Investigations of platinum metals at the Bureau of Standards (E. Wichers and L. Jordan, *Trans. Am. Electrochem. Soc.* 43; May meeting, 1923).
- The preparation of platinum and platinum-rhodium alloy for thermocouples (R. P. Neville), *Trans. Am. Electrochem. Soc.* 43; May meeting, 1923.
- The decarburization of ferro chromium by hydrogen (L. Jordan and F. E. Swindells), *Sci. Paper* 448; also *Chem. and Met. Eng.*, 27, p. 1071; 1922.
- Gases in metals: I. The determination of combined nitrogen in iron and steel and the change in the form of nitrogen by heat treatment (L. Jordan and F. E. Swindells), *Sci. Paper* 457; also *Chem. and Met. Eng.*, 27, p. 1135 and 1170; 1922.
- The preparation and properties of pure iron alloys: I. Effect of carbon and manganese on the mechanical properties of iron (R. P. Neville and J. R. Cain), *Sci. Paper* 453; also *Trans. Am. Electrochem. Soc.*, 42, p. 21; 1922.
- Gases in metals (L. Jordan), *Proc. Am. Soc. Test. Mat.*; June meeting, 1923.
- The effect of high-temperature quenching on the microstructure of high-carbon steels (H. Scott), *Trans. Am. Soc. Steel Treat.*, 3, pp. 593-623; 1923.
- The magnetic change in silicon and in chromium steels (H. Scott), *Chem. and Met. Eng.*, 28, p. 212; 1923.
- The decomposition of martensite into troostite in alloy steels (H. Scott), *Forging and Heat Treatment*, 8, p. 296; 1922.
- Contribution to discussion, What is steel? (H. Scott), *Chem. and Met. Eng.*, 27, p. 1156; 1922.
- The mechanical properties of chrome vanadium steels (J. S. Vanick), *Trans. Am. Soc. Steel Treat.*, 3, p. 196; 1922.
- Thermal transformations in some chrome vanadium steels (J. S. Vanick) and W. W. Sveshnikoff), *Trans. Am. Soc. Steel Treat.*, 3, p. 502; 1923.
- The magnetic susceptibility and iron content of tin-red-brass (L. H. Marshall and R. L. Sanford), Tech. Paper 221.
- Review of present status of drill-steel breakage and heat treatment (F. B. Foley, C. Y. Clayton, and H. S. Burnholz), *Trans. Am. Inst. Min. and Met. Eng.*, pamphlet 1206-M; 1923.
- Hardness and heat-treatment of mining drill shanks (C. Y. Clayton), *Trans. Am. Inst. Min. and Met. Eng.*; pamphlet 1208-M; 1923.
- Influence of temperature, time, and rate of cooling on the physical properties of carbon steel (H. M. Howe, F. B. Foley, and J. R. Winlock), *Trans. Am. Inst. Min. and Met. Eng.*; pamphlet 1226-S; 1923.

Publications in press:

- A comparison of the deoxidation effects of titanium and of silicon on the properties of rail steel (G. K. Burgess and G. W. Quick); Tech. Paper.
- Invar and related nickel steels, Circular 58 (rewritten) (E. C. Groesbeck).
- Nickel, Circular 100 (revised) (E. C. Groesbeck).
- The crystalline form of electrodeposition of metals (W. Blum and H. S. Rawdon), *American Electrochem. Soc.*

- Embrittlement of malleable cast iron produced by heat treatment, as revealed by impact tests (L. H. Marshall).
- Tensile properties of carbon and alloy steels at high temperatures (H. J. French and W. A. Tucker), *Iron Age*.
- Lathe breakdown tests for the purchase of high-speed steels (H. J. French and Jerome Strauss), *Forging and Heat Treating*.
- Deterioration of steel and wrought iron tubes in hot, gaseous ammonia (J. S. Vanick), *Trans. Am. Soc. for Steel Treating*.
- Note of the swelling of machine gun barrels (W. W. Sveshnikoff), *Army Ordnance Journal*.



CERAMICS.

P. H. Bates.

FUNCTIONS.

The work in connection with ceramics deals with standards of quality, methods of test, and specifications for ceramic materials and products; the study of problems relating to the preparation and utilization of ceramic materials and to the manufacture of ceramic products; the elimination of waste by supplying definite guides to purchasers, Governmental and private, and by obtaining and disseminating to manufacturers scientific information of assistance in the improvement of products and in increasing the efficiency of methods. The products embraced in this work include building materials, such as brick, hollow tile, wall tile, and architectural terra cotta; drainage materials, such as sewer pipe and draintile; paving materials, such as paving brick and floor tiles; refractory materials required for the lining of metallurgical and other furnaces; pottery and porcelains, including dishes, sanitary ware, electrical porcelain, and chemical porcelain; glass products, including window glass, glass containers, and optical glass; and products made by the enameling of sheet iron or sheet steel, cast iron, and other metals.

SECTIONS.

1. Pottery and fine ceramics.
2. Optical glass.
3. Refractories.
4. Enameled metals.

GENERAL STATISTICS.

Staff	30
Expenditures (1922-23)	\$62,000
Tests completed	12,283
Researches completed	8
Bureau publications	2
Other technical publications	11

WORK CHART.

I. POTTERY AND FINE CERAMICS.

SCOPE.

Investigation dealing with: (a) Tableware (earthenware, porcelain), (b) architectural terra cotta, (c) tile, (d) art pottery, (e) chemical and high-temperature porcelain, (f) stone ware.

Comprising studies of effect on finished product of: (a) Raw materials, (b) manufacturing processes, (c) burning conditions.

Leading to development of tests: (a) Chemical, (b) physical, (c) petrographic.

Standards of quality and service.

TESTS.

Material tested.	Number completed.	
	1921-22	1922-23
Raw materials.....	350	500
China.....	2,500	900
Matt glazes.....		40
One-fire porcelains.....		1,500
Casting slips.....		20
Tank linings.....	30	55
Terra cotta.....	160	230

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent ^a completed.	Publication issued.
Physical properties of vitreous china bodies.....	American Vitrified China Manufacturers	100	Outside. ¹
Standard specifications for "whiteware".....		50	Do. ²
Properties of American and English ball clays:	American Pulp and Paper Association.		
Raw materials.....		100	T227.
Products.....		100	
Investigation of potters flint in pottery bodies.....		50	
Zinc matt glazes.....		10	
A study of clay suspensions by means of the hydrogen electrode.....	Association of Tile Manufacturers.	75	Outside. ³
Plasticity of paper clays.....		80	
Crazing of semiporcelain dinner ware.....	National Terra Cotta Society.	30	
Cements for setting tiles.....		65	
Study of physical properties of terra cotta:	do.....		
Physical tests of specimens.....		85	
Burning conditions in terra cotta plants.....		10	

¹ Jour. Am. Ceram. Soc., August, 1923.

² Jour. Am. Ceram. Soc., February, 1923.

³ Jour. Am. Ceram. Soc., September, 1923.

2. OPTICAL GLASS.

SCOPE.

Manufacture of optical glass: (a) Raw materials, (b) processes, (c) testing, (d) annealing.

Sheet glass: (a) Strength, (b) wind resistance, (c) specifications.

Glass containers: (a) Manufacture, (b) physical properties, (c) service conditions.

Glass tableware: (a) Physical properties, (b) specifications.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Chemical analyses.....	60	120
Miscellaneous.....		155
Action of water, etc., on glass.....	277	924
Mold temperatures.....		25
Physical tests.....	5,000	1,060
Optical glass:		
Glass melted—		
Routine.....	lbs. 23,000	19,000
Experimental.....	pots. 23	19
Glass molded, annealed, inspected, and approved ¹ —	lbs. 6,000	11,400
By hand.....	pots. 4	11
As slabs.....	lbs. 1,839	1,806
Stock of blanks accumulated (approximately).....	pieces. 7,775	9,407
	lbs. 808	374
	pieces. 77	43
	lbs. 300	300
	pieces. 3,000	3,000

¹ Delivered to the Naval Optical Shop, Navy Yard, Washington, D. C.

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Composition and optical properties of glasses.....		25	
Study of physical properties of glass.....	Glass Container Association.	75	Outside. ¹
Seumming of glass bottles.....	do.	75	Do. ²
Specifications for sheet glass.....	Manufacturers of sheet glass.	90	
"Stones" in glass.....		95	

¹ Jour. Am. Ceramic Soc., April, 1923.

² Jour. Am. Ceramic Soc., December, 1922.

3. REFRACTORIES.

SCOPE.

Structural clay products: (a) Brick (b) hollow tile, (c) drain tile.

Refractories: (a) Fire-clay brick, (b) silica brick, (c) magnesite brick, (d) chrome brick, (e) special.

Glass-tank blocks and glass pots:

Investigations of—

(a) Raw materials.

(b) Manufacturing processes.

(c) Commercial uses.

To develop standards of—

(a) Tests.

(b) Quality.

(c) Use.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Commercial.....	408	425
Fire-clay refractories.....	677	1,731
Water smoking and dehydration.....	320	.....
Sagger clays.....	320	928

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.	
		Per cent completed.	Publication issued.
Study of refractories:			
Brick for stoker-fired boiler settings.....	{Refractories Manufacturers Association, Store & Webster.}	75	
Brick for rotary cement kilns.....		20	
Resistance of glass pot bodies to glass.....		100	
Problems relating to saggars.....	United States Potters Association.	30	
Water smoking and dehydration of clays.....	Heavy Clay Pro- ducers' Associ- ation.	100	

4. ENAMELED METALS.

SCOPE.

Enameling of: (a) Ferrous metals, (b) nonferrous metals.

Effect on finished ware of: (a) Raw materials, (b) compositions, (c) melting, (d) surface of metal.

Developing standards of: (a) Test methods, (b) quality.

TESTS.

Nature of test.	Number completed.	
	1921-22	1922-23
Raw materials.....	75	50
Plates burned 3 coats.....	1,450	1,850
Enamels:		
Physical.....	1,100	1,700
Chemical.....	75	70

RESEARCHES.

Subject.	In cooperation with—	Status June 30, 1923.		
		Per cent completed.	Publication issued.	
Sheet-steel enamels for kitchenware:				
Composition and physical properties.....	} oonley Manu- facturing Co. }	100		
Application of results.....		95		
Warpage of enameled sheet iron and steel.....	} American Ce- ramic Society, enamel divi- sion. }	90		
Cast iron for enameling purposes.....		70		
Some substitutes for tin oxide in white enamels.....		100		Outside. ¹
Specking of ground coat enamels.....		100		

¹ Jour. Am. Ceramic Soc., May, 1923.

Detailed Report of the Year's Work.

I. POTTERY AND FINE CERAMICS.

H. H. Sortwell.

Physical Properties of Vitreous China Bodies Fired at Different Temperatures (Sortwell).

As a result of a meeting of the research committee of the United States Potters Association with the Bureau of Standards, an investigation was started dealing with the effect on the finished body of different compositions and temperature conditions prevailing throughout commercial kilns. A member of the bureau's staff visited the potteries of the American Vitrified China Manufacturers' Association for the purpose of making specimens for transverse, compressive, and impact strength tests and porosity determinations. The specimens were fired in three different locations in a kiln at each factory in order to obtain samples burned under average plant conditions, and were then tested at the bureau. The differences in the bodies showed emphatically the serious effect of underfiring and overfiring on the physical properties of such wares.

In addition to this, each of the 11 potteries shipped a quantity of plastic body to the bureau, where it was made into specimens and fired at cones 6, 8, 10, 12, and 14, covering a much wider range in heat treatment than exists in the pottery kilns. These tests gave the same results as the previous tests. While some of the bodies had a comparatively long burning range, most of them matured and overfired within narrow limits. A complete report of the work has been submitted to potters who cooperated in the work, and for publication in the Journal of the American Ceramic Society.

Development of a One-Fire Porcelain (Sortwell).

A combination of body and glaze for the manufacture of porcelain in one fire—that is, maturing body and glaze at the same time—has been developed for the economical and rapid production of white-ware products. The work, which consisted of casting and firing a large number of pieces, involved studies of the effect of variation in clay content on casting behavior, the amount of electrolytes for proper deflocculation of such bodies for casting, the relation of methods of mold making to the wearing qualities of the molds, the effect of variations in glaze composition on body fit in the one-fire process, and the effects of variation in temperature and kiln atmosphere on overglaze color. Further work should be done, especially a study of water content and salts to be used in the casting of bodies of very low or no ball clay content.

Tests of Porcelain Sanitary China (Sortwell, Fair).

Ten brands of porcelain lavatories have been given a long series of tests to study the advisability of the use of a hot and cold water test in the specifications of the Federal Specifications Board. The conclusions from the work were that a hot and cold water test would not be severe enough to show any difference in the average run of the wares in a reasonable length of time. Further tests were made by quenching the lavatories from a furnace at temperatures of 100, 120, 140, 160, 180, and 200° C. in water at 15° C. These tests

showed differences in the 10 brands of ware tested with respect to their ability to withstand sudden temperature changes. Results obtained do not justify the formulation of specifications.

Specifications for Tableware (Sortwell, Hazelwood).

In order to establish relations between thickness of tableware and resistance to impact, further physical tests have been made. Two of the brands tested were semiporcelain hotel ware and two were vitrified porcelain hotel ware. It was found that in all types tested the impact to cause "starring" increased with the thickness in an approximately parabolic relation. In plain semiporcelain dinner ware and rolled edge vitrified hotel china, difference in thickness within the range in which such ware is ordinarily made had no appreciable effect on the ability of the ware to withstand complete failure by impact. A report has been given the potters and was published in the February, 1923, issue of the *Journal of the American Ceramic Society*.

In connection with these laboratory tests, service tests are being conducted in cooperation with the American Hotel Association at the Willard Hotel, Washington, D. C., and the Biltmore and Waldorf-Astoria Hotels, New York, N. Y. Additional samples are being sent to other hotels for this purpose.

Bonding Power of Ball Clays in Fired Bodies (Sortwell, Shearer).

In addition to the investigation of ball clays which has been reported in Technologic Paper No. 227, a further study of the clays has been made to determine the comparative effect of the various clays on the strength of fired bodies. Twenty-five ball clays, both American and English, were used in making experimental bodies, containing 50 per cent nonplastic refractory material, which were fired at several temperatures and the transverse strengths determined. Wide differences in the bonding power of the clays in the absence of active fluxes were noted. A few bodies were then made for comparison of the bonding power of the clays in bodies containing no fluxes with semiporcelain and vitreous china compositions containing feldspar, which promotes vitrification. The results of this preliminary study indicated that the strength of bodies containing feldspar might differ but slightly with different ball clays, but that no relation exists between such bodies and those in which no flux is used. The report of this work has been submitted for publication in the *Journal of the American Ceramic Society*.

Cement for Setting Tile (Gaardsmoe).

Rapid increase in the use of tile for lining tanks in various industries has brought to the attention of manufacturers of this commodity that the cements now available possibly do not give satisfactory service. The bureau has been conducting work along the line of developing cements to resist the action of such solutions as acid storage battery electrolytes, photographic fixing solutions, photographic developers, meat pickling solutions, paper stock bleach, and solutions of aluminum sulphate. Concrete tanks are being constructed which are being lined with tile set in certain of the acid-proof cements in common use. After aging these are being filled with the solutions indicated and the behavior of the cement in serv-

ice noticed. The work has not progressed sufficiently to permit any conclusions to be drawn.

Zinc Matt Glazes (Sortwell).

Matt glazes of this type are important commercially, but the published information on compositions is very meager. A study of compositions suitable for this type of glaze maturing at several temperatures is under way.

Potters' Flint (Shearer).

American potters use three distinct types of silica in their bodies: quartz, American cryptocrystalline silica, and French flint. An investigation is being conducted to determine their comparative effects in semiporcelain, sanitary porcelain, and vitreous china bodies. Seventeen samples, representing all three types, have been collected and are being tested for a comparison with the specifications for flint proposed to the American Ceramic Society by their committee on standards.

Study of Humidity Problems (Lindsay).

A study of the effect of different rates of drying of clay under different humidity conditions is under way. The first phase of this study consists in the determination of the effect of drying treatment on the strength and other properties of laboratory test specimens made from different types of clays and from commercial bodies. A large part of this work will be done in a drier permitting accurate control of temperature and humidity conditions.

In cooperation with the heat and power division and the Weather Bureau, work in the study of theoretical psychrometry and hygrometry is being carried out. The work now consists mainly in assembling data preparatory to publication. The ultimate object is the establishment of more reliable and accurate tables relating to the condition of water vapor in air and the verification of the laws of evaporation.

United States Potters' Association Research Associate (Roehm).

This investigation is a study of the cause and control of the crazing of semivitreous china.

The work is being conducted on commercial bodies and on specimens of ware submitted by manufacturers. The investigation involves: (a) A study of physical properties, such as rate of vitrification, transverse strength, absorption, and coefficient of expansion of this type of ceramic body; (b) the effects of glaze thickness; (c) the effect of varying thicknesses in the ware on which the glaze is used; and (d) a correlation of physical properties with results obtained by the glazing of specimens under varying conditions of glaze and body thickness and methods of burning.

A complete report of the progress of this investigation has been submitted to the association.

A Study of Clay Suspensions (Hall).

This is a part of the program of studies of those physical-chemical properties of clays which must be more clearly defined and understood before satisfactory progress can be made in the preparation of specifications for clays for specific purposes and in the improve-

ment of such processes as the purification of clays and the casting of porcelain and other ceramic wares.

The work on the study of clay suspensions has dealt mainly with methods of determining the hydrogen-ion concentration which affects the stability of such suspensions. The two methods finally adopted were the colorimetric method and the hydrogen-electrode method. The water extracts from 50 different clays, including ball clays, kaolins, and fire clays were examined by these methods. The pH value for these varied from 3.0 to 8.5. The rate of settling of a clay in water is greatly influenced by the pH value of the suspending medium. The rate of settling of six different clays over a wide range of pH value was studied and they all exhibited a maximum rate of settling on the acid side (the iso-electric point), and a minimum rate of settling on the alkaline side (the point of maximum deflocculation). Knowing these two points for a given clay, it is possible to attain a high degree of efficiency in the separation of clay material from impurities, such as coarse grain quartz and mica.

The action of alkali on 11 clays was studied by means of the hydrogen electrode, and the amount of alkali absorbed by a clay suspension was determined. From the data collected it seems that the action of alkali on clays over the range pH 7-12 is a case of physical absorption. In solutions more strongly alkaline than pH 12, there is probably a chemical reaction between the alkali and the clay. By plotting the two constants of the absorption equation as determined for the 11 clays, they are divided into three classes, namely, ball clays, kaolins, and china clays. This will probably give some clue as to the distribution of the grain size of the several clays.

Thermocouple Protection Tubes (Insley).

It has been noted that the high-fire porcelains used in the manufacture of thermocouple protection tubes generally fail very rapidly in glass-melting furnaces though they may give very satisfactory results in the usual type of ceramic kiln. Petrographic examinations have been made of such failed tubes and it has been found that the alkali volatilized from the melt produces a conversion of the sillimanite originally present into corundum imbedded in a glass composed of a complex silicate, high in alkali.

Study of Physical Properties of Architectural Terra Cotta (Fuller).

The first phase of this investigation which is being conducted in cooperation with the National Terra Cotta Society, and which involved a series of physical tests on specimens of terra-cotta bodies, is nearing completion. During the past year studies of the properties of terra-cotta bodies included determination of hardness, resistance to abrasion, resistance to actual freezings, permeability, and porosity. Striking differences in permeability have been shown, but there is no consistent relation between the permeability and absorption values for the bodies studied. All the bodies resist actual freezing so well that although approximately 350 actual freezings have been made on 4 by 1 by 1 inch specimens of bodies produced by a number of manufacturers, only slight effects have been observed and it is, therefore, impossible to correlate resistance to freezing with any of the other properties determined.

A new program of tests of freezing and weathering resistance on a large number of special coping blocks, balusters, special freezing specimens, and bars made by four different manufacturers and burned in different parts of their kilns has been undertaken. A representative of the bureau visited three plants in the East, which have been designated to make and burn these specimens, and a survey of temperature conditions in different parts of the kiln in which the specimens were burned was made in order that variations in burning conditions and the resultant effect on the quality of the ware could be studied. A similar set of specimens will be made and burned at a plant in California. In addition to the specimens made from the regular terra-cotta bodies, coping blocks and balusters are to be made up from an especially porous terra-cotta lumber body and from especially dense bodies, such as stoneware and electrical porcelain.

2. GLASS—OPTICAL GLASS.

A. E. Williams.

General.

The relations between the chemical composition of various kinds of glasses and their physical and optical properties have been further investigated. This work included investigations of: (*a*) Plant and laboratory methods of melting glass and the molding, annealing, and testing of glass products; (*b*) the resistance of glass to weathering and the solvent action of water; and (*c*) the strength of glass for glazing.

These investigations have resulted in the accumulation of a vast amount of data regarding the various phases of the glass industry and the properties of glass, which have enabled the bureau to render considerable assistance to the manufacturers in improving the quantity and quality of their product. They have also enabled the bureau to recommend specifications and tests for several types of glassware, which make it possible for the consumer to obtain supplies that will give the maximum service.

Methods of Testing (Williams, Palmer, Hazelwood).

Development of test for resistance to weathering.—Work to devise methods for determining the resistance of glass to solution in water and the comparative resistance of glass used for container purposes has been completed. As a result a basis of comparison for the quality of glasses in this respect has been obtained. This work was reported in the *Journal of the American Ceramic Society*, vol. 6, No. 4 (1923).

Study of strength tests for sheet glass.—Sheet glass for glazing purposes has been tested in frames for comparison with the results of the simple transverse strength tests previously made. The testing of small samples and of large lights in frames is being continued in order to get an accurate survey of the variations in the strength of glass as produced by different manufacturing variables. Results indicate that the simple tests on small samples can be interpreted into values obtained on large plates.

Scumming or Weathering of Bottles (Williams, Ford).

Samples packed and stored under various conditions for a period of six months have been removed from storage and examined. The

results indicate that conditions of damp storage and certain types of packing, such as wrapping tightly in paper, favor the production of scum.

A study of the physical and chemical condition of the glass surface as compared with the interior layers of the article is being made with a view to reducing the tendency of glasses to scum by producing a more resistant surface. The results of this work were reported in the *Journal of the American Ceramic Society*, volume 5, No. 12 (1922).

Specifications for Glazing Glass (Williams).

As a result of tests made by the bureau and of several conferences between manufacturers and consumers of glass for glazing, tentative specifications have been prepared in which nomenclature, definitions, classification, faults, size, tolerances, etc., are discussed. Agreement to these specifications is practically unanimous, but they have not yet been adopted.

Specifications for Milk Bottles (Williams).

Conferences with manufacturers, cap makers, milk dealers, and dairy inspectors have been held at which plans were discussed to standardize the shapes, capacity, marking, and labeling of milk bottles, and to consider the possibilities of adjusting State and municipal laws and regulations to conform to such standards. Methods of marking were adopted and the Bureau of Standards was delegated to present this phase of the work to the State and municipal authorities concerned.

Work for Federal Specifications Board (Williams).

Work on the preparation of specifications for glass and chinaware for use in all Government departments is being conducted by this division in cooperation with various Government departments. A suitable specification has been prepared and a tentative set of chinaware has been adopted by the Government representatives. This will be referred to the potters association for comment. Tentative specifications for four types of glassware have been adopted and are now in the hands of manufacturers for comment and criticisms.

Optical Glass.

Melting (Finn).—Thirty pots of optical glass were melted, in which the following types were produced:

Kind of glass.	Number of pots.
Boro-silicate crown ($N_d=1.520$)	18
Light crown ($N_d=1.524$)	5
Light barium crown ($N_d=1.574$)	2
Medium flint ($N_d=1.620$)	3
Dense barium crown ($N_d=1.622$)	1
Extra dense flint ($N_d=1.774$)	1

The relatively large proportion of boro-silicate glass was made to supply the naval optical shop, which calls for very large quantities of this glass in the form of flat, lens, and prism blanks. The experience derived from the numerous melts of this glass now enables the bureau definitely to state the conditions under which a good quality of this glass can be made in relatively short time, and it has also been demonstrated that a superior quality of this glass can be made entirely from rejected glass (cullet).

The melts of light crown have not yet been entirely successful. The melting of light barium crown and medium flint gives very satisfactory glass. The time required for the first of these is at present probably somewhat longer than is actually necessary, but the demands for this glass and the funds available have not justified the large number of melts required to make a comprehensive study of variations in melting operations.

A decided improvement in the color of the dense barium crown was obtained by modifying the batch composition. This type of glass has a decided tendency to be green in color, and in order to be suitable for high-speed photographic lenses it should be relatively free from color.

The dense flint melt is satisfactory for prisms for direct vision spectroscopes, although it contains some seeds and is distinctly yellow in color.

A water-cooled iron pipe, as used in Scotland for stirring the molten glass, has been successfully substituted for the clay rods previously used in the bureau's work. The iron stirring rod can be handled much more easily and its use obviates the necessity of making a new clay rod for each melt.

Molding (Finn).—Approximately 12,000 satisfactory optical blanks have been molded by the "sticking-up" process. These include lens blanks varying from 15 millimeters in diameter, weighing 15 grams to penta prisms, with a 63-millimeter face, weighing 1,000 grams.

A number of slabs varying from 15 by 5 to 22 by 10 centimeters, and weighing from about 3 to 12 kilograms, have been molded by heating the glass in clay molds. Three large disks weighing from 100 to 150 kilograms and about 75 centimeters in diameter by 8 centimeters thick have been made by a similar process. In order to obtain larger pieces of glass for this purpose, seven pots of boro-silicate glass have been cooled in various ways, to determine, if possible, the cooling conditions necessary to yield the entire melt in one piece. The problem is rendered somewhat complex by differences between the thermal expansion of the glass and that of the pot body.

Annealing (Finn).—Much of the glass molded has been annealed in an electric furnace. The operation of this furnace, which was designed and built at this bureau and is now equipped with an automatic temperature regulator, is very satisfactory, and it is relatively easy to reduce the strain in the largest prisms and penta prisms to less than 10 μ per centimeter.

Inspection (Finn).—A combination of the immersion method and the shadow-projection method has been found to be more rapid and more sensitive for detecting striæ than either method alone. This procedure makes it possible to examine slabs, etc., after rough grinding, obviating the extra work incident to polishing.

The estimation of strain in molded blanks is found to be more reliable if they are immersed in the proper liquid during examination since it is difficult, if not impossible, to detect small, irregular strains in molded blanks without polishing or immersing them. This is especially desirable on account of the unsatisfactory optical performance resulting from small, irregular strains. (See Experimental strain.)

Disposition.—Approximately 2,200 pounds of glass, representing over 9,500 pieces, have been delivered to the naval optical shop on Ordnance Bureau requisition No. 222 (1922). In addition to this, about 3,000 lens blanks varying from 15 to 110 millimeters in diameter have been prepared as stock for the Bureau of Standards.

Glass pots (Geller, Finn).—The glass pots which were made last year and are being used this year are giving excellent results. The modifications in the composition of the pot body and method of burning, which has been radically changed during the past year, gives pots which are extremely resistant to the most corrosive glasses. The pots are completely burned in pot arches, the rate of heating being very slow up to 800° C. and then more rapid (25° per hour) until the critical temperature (about 1,425° C.) is reached. This temperature, which is maintained for eight hours, is just below that at which the pot becomes sufficiently soft to deform under its own weight.

Experimental chemical (Finn, Thompson).—The chemical analysis of the glasses made at the bureau is well under way. This important investigation is being conducted with a view to establishing the relation between chemical composition and optical constants. Such data should enable one to predict definitely what optical constants can be obtained and what batch composition will give the desired results.

Experimental strain and its relation to optical performance (Finn).—Several cases of poor definition have been referred to the bureau by the naval optical shop and whenever the trouble could not be attributed to striae the glass was found to be irregularly strained, and the trouble was entirely corrected by proper annealing.

Viscosity of Glass (Williams, Palmer).

Apparatus for measuring the viscosity of glasses at different temperatures has been designed, assembled, and calibrated. Tests on three samples of soda-lime glass indicate that it may be plastic in nature rather than viscous. This is also apparently true of 90 per cent glucose solutions.

Classification and Identification of "Stones" in Glass (Insley).

Studies of "stones" in glass were made to determine their nature and origin and to suggest methods for preventing their formation, since they are the source of considerable losses to the glass industry. Approximately 200 samples of glass containing "stones," which are crystalline segregations or undissolved extraneous matter, were examined and found to result from unsatisfactory furnace conditions, faulty batch compositions, and poor refractories. Stones resulting from these causes are easily identified with a polarizing microscope and with proper precautions can be practically eliminated. The results of this investigation were published in the *Journal of the American Ceramic Society*, vol. 6, No. 6 (1923).

3. HEAVY CLAY PRODUCTS—REFRACTORIES.

W. A. Hull.

Study of Refractories (Geller).

In cooperation with an advisory committee composed of producers and consumers of refractories, the bureau has undertaken

the establishment of specifications to be used by various Government departments in the purchase of refractories. The present work deals specifically with refractory brick for the lining of stoker-fired boiler settings and consists in subjecting brick of a representative number of brands to tests, as suggested at the last meeting of the advisory committee held at the bureau. The results of the laboratory tests are then to be correlated with service records on brick of the same brands, which are being gathered from the various power plants. With these data it is hoped to establish certain values by means of which the suitability of a given brand of brick for stoker-fired boiler service can be determined in the laboratory.

Brick were obtained representing 42 brands, supplied by users in all of the important industrial districts of the country. A representative number of specimens of each have been subjected to the standard and modified load tests, and the endurance, constant volume, and quenching tests. Absorption tests before and after various heat treatments, the fusion points, and chemical analyses of each brand were determined.

The results of the load test check closely with those obtained in previous investigations and show clearly the relative behavior of brick from various districts of the United States. Results of the investigation also indicate a close relation between chemical composition, fusion point, and resistance to sudden temperature change, and these also agree quite satisfactorily with the results of the endurance and constant volume tests. The laboratory work of the investigation has been completed. The data obtained, although of great interest and value, can not be used as a basis for specifications until correlated with service records which are now being collected.

Brick for Rotary Cement Kilns (Geller, Pendergast).

Samples of commercial refractories for this type of kiln have been obtained from four manufacturers and one consumer. A representative number of specimens will be subjected to recognized tests for refractories, including: (1) Constant volume and quenching tests, (2) a modified slagging test, (3) load test for high-duty brick, and (4) fusion point.

From the data obtained it is proposed to establish relative values of clinker and fire clay brick and to determine the relation between the commercial value of the fire-clay refractories and their alumina content.

Investigation of the Resistance of Various Types of Glass Pots to the Corrosive Action of Glass (Geller).

Twenty pots, each having a capacity of approximately 1,000 pounds of glass, were made by the casting process and delivered to the glass section of this division to be used in the production of optical glass. A remarkable opportunity is afforded in this way to study on a commercial scale, but with laboratory precision, the effect of varying body compositions and methods of burning on the resistance to the corrosive action of the glass. A complete report of observations on pots of varying compositions, and their resistance to glass corrosion as affected by different burning treatments and types of glass, has been submitted for publication to the Journal of the American Ceramic Society.

Three glass pots, having a capacity of approximately 4,300 pounds of glass each, have been cast and are to be used in a special glass investigation. The manufacture of these pots involved the forming of a plaster mold considerably larger than any previously made at the bureau. Ten tons of plaster of Paris were used in the forming of the various parts of the mold, and many instructive points were brought out relative to preparation, casting, and turning down of the plaster to the desired form. The casting of the special glass pots, each of which required approximately 3,000 pounds of slip, offered no particular difficulties.

Sagger Investigation (Geller).

A comprehensive study of problems relating to sagers has been undertaken, beginning with a survey of the important types of clays used in sagger making in different parts of the United States. Samples of approximately 60 sagger clays have been obtained, and their physical properties are being studied, and, in addition, test specimens are being made of sagger mixes used by several different potteries. Samples made from these mixtures, together with samples made from individual clays included in the mixtures, will be burned in the potteries and the progressive changes in their physical and chemical properties in the course of successive burnings in pottery kilns will be studied. The pottery manufacturers who have been asked to furnish considerable quantities of clays, and those who have been asked to cooperate in the investigation by burning test specimens in their kilns, have responded heartily.

Heavy Clay Products Investigation (Geller, Hazelwood).

The work on water smoking and dehydration of clays, which was undertaken in connection with the Cooperative Heavy Clay Products Investigation, has been completed. This work included water smoking and dehydration of 4-inch cubes made from clays and shales sent in from 14 plants at which burning processes were studied by the Bureau of Mines. The water smoking and dehydration studies were made in an electrical furnace so equipped that temperatures could be measured at different depths in the cube and the loss of weight could be determined during the water smoking and dehydration. Both processes were carried on at different rates in order to determine the effect of the rate of water smoking and the rate of dehydration on the specimen, and on the temperature distribution within it, as well as on the rate of loss of weight. Runs were also made in which the specimen was heated by stages, the temperature being held constant at the end of each stage until the weight became practically constant. The purpose of this was to determine how much of the weight loss would take place at a given temperature if sufficient time were allowed. This has a particular bearing on the question of burning and the results showed that loss of time, especially in water-smoking period, would result from holding the temperature in a kiln constant for a considerable period instead of keeping it consistently rising. The results of the investigation show distinctly the differences in behavior of different types of clays and shales in the water smoking and dehydration periods, and in the report which has been rendered to the technical committee of the Heavy Clay Products Association the results show in

a somewhat striking manner means and methods by which kiln time and fuel could be conserved in the burning of heavy clay products in intermittent kilns. The data obtained will be of value to those who are engaged in the development of continuous kilns and the improvement of continuous-kiln practice.

Behavior of Refractories in Glass Tanks (Insley).

In order to determine the cause of failure in glass-house refractories a study of the change in the constitution and structure of refractories used in different parts of glass-melting furnaces has been undertaken.

4. ENAMELED METALS.

R. R. Danielson.

Sheet-Steel Enamels for Kitchen Ware (Danielson).

Preliminary tests of ability to withstand impact, acids, and quenching, made for the purpose of providing data for enameled kitchen ware specifications, showed such great differences in commercial ware that one of the large manufacturers of such wares is cooperating with the bureau in an extended investigation of the relation of enamel composition to these physical properties. The cooperating company stationed a man at the bureau to assist in the work and has contributed 3,000 dinner plates of their regular sheet-steel stock for use in the investigation.

A large variety of compositions for both ground coat and cover coat enamels have been made and applied to the stock. The finished plates have been tested for acid resistance, ability to withstand impact, and resistance to thermal shock. In addition, the effect of underfiring and overfiring is being studied. The work is well under way and when completed the results will be applied on a larger scale in the cooperating factory.

Warpage of Sheet Iron and Steel (Hartshorn).

In the manufacture of table tops and other sheet-iron and steel ware considerable loss is incurred by the warping of the stock during the manufacturing processes. An investigation is under way to determine the causes and methods of control of the tendency of enameled sheet-iron and steel wares to warp.

A number of typical metal stocks now in use have been obtained. Different cleaning methods and annealing treatments are being studied, and a variety of typical ground and cover coats are being applied to determine the effect of enamel fit on warping. A progress paper on this investigation was presented at the annual meeting of the American Ceramic Society in February, 1923. The data obtained indicate a relation between the hardness of the enamel and the method of cooling and the amount of warpage produced in the finished product.

Cast Iron for Enameling Purposes (Danielson).

There is almost a total lack of reliable information on the composition of cast iron suitable for the manufacture of enameled bathtubs, stove parts, etc. A manufacturer having great success with cast iron from one source may meet considerable trouble when forced

to change his source of supply. Samples of a large variety of enameled cast irons from a number of factories have been shipped to the bureau. In cooperation with the metallurgy division, the specimens have been examined microscopically and the chemical analyses have been made. The information obtained is not sufficient to satisfactorily distinguish poor irons. Gas analyses and further enameling tests are in progress to determine causes of blistering and pinholing.

Some Substitutes for Tin Oxide in White Enamels for Sheet Steel (Danielson, Frehafer).

The price of tin oxides makes it desirable to use cheaper opacifying agents in white enamels if as satisfactory results can be obtained. About 25 opacifying agents, including all of the substitutes for tin oxide now on the market, and several other possible compounds have been incorporated in a standard commercial composition and compared with the same composition made with several brands of tin oxide. The opacity of the resulting enamels has been determined by the light division, and they have been examined for texture and gloss.

In general, the results showed that none of the substitutes were equal to tin oxide as an opacifying agent. A number of antimony compounds gave good results, and zirconium oxide and silicates served very well. However, any economy effected by the elimination of the tin oxide would be accompanied by a sacrifice in the appearance of the enamel. It is possible, however, that one or more of the proposed substitutes for tin oxides might give better results in enamel of some other composition than in the one in which they were tried in this investigation. The results of the work have been presented before the enamel division of the American Ceramic Society, and the report has been published in the May, 1923, issue of the *Journal of the American Ceramic Society*.

Specking of Ground-Coat Enamels (Danielson).

A preliminary investigation has been conducted to study the causes of "specking" of ground-coat enamels. This defect appears as spots of oxide or slag in the first enamel coating and is detrimental to the appearance of the ware.

A number of steel cups have been coated with a regular stock enamel for observation.

Results indicate that this "specking" is due to a rusting of the metal, caused by an excess of acid or salts in the enamel. It can be remedied by the addition of sufficient sodium hydroxide previous to the dipping operation. A report on this investigation has been made before the enamel division of the American Ceramic Society.

TESTING, INFORMATION, AND PUBLICATIONS.

It is gratifying to be able to say that the demands made upon the division for "analyses" of clays have materially fallen off. The general public is apparently learning that the analyses or tests of clay which may happen to come to its attention are of very little value in themselves to anyone. It is far more important to know the extent of the deposit of the clay and its uniformity than to know the properties of a small sample which may be picked up some

place. The public is also beginning to realize the necessity of studying not only the extent and character of the deposit, but the need of going into the question of plant financing and also the marketing of whatever product is made. Realizing these points, the demand for general information as to the value of small samples of clay is falling off rapidly.

At the same time the amount of testing is increasing. This testing is, however, generally the result of investigations being carried on at the bureau, often in cooperation with an association or a corporation. Though it may appear as a test or a series of tests, it is in reality a part of a research, for certain lines of investigative methods have reached such a condition that many types of testing have become, even in the case of research, routine.

The cooperative work between various technical associations and the bureau has been most gratifying during the past fiscal year. In several instances the members of the associations permitted the bureau to conduct tests at their plants. In this way the bureau was able to extend to actual plant operations certain of the observations which it had been carrying on only on a semiplant scale at the laboratory. Among such cases may be mentioned the assistance of the American Vitriified China Manufacturers' Association and the National Terra Cotta Society. In both cases a large number of test pieces were prepared at the plants according to the usual plant routine, observations on this routine being made by representatives of the bureau. The specimens were sent to the bureau for test.

Tests Completed During the Year.

During the year the following tests have been completed by the various sections of this division:

Raw materials (clays, flints, spars, etc.)-----	500	Physical tests of glass-----	1,060
China ware-----	900	Chemical analyses-----	120
Tank linings-----	55	Sagger clays-----	928
Matt glazes-----	40	Terra cotta-----	230
One-fire porcelains-----	1,500	Fire-clay refractories-----	2,156
Casting slips-----	20	Three coat enamel burns-----	1,859
Action of water on glass-----	924	Physical tests of enamels-----	1,700
		Chemical tests of enamels-----	70

Optical Glass production.

	Pounds.
Routine-----	19,000
Experimental-----	11,400
Molded and annealed-----	2,480

Cooperation with Technical Societies.

The cooperation with the bureau of the various technical societies interested in ceramics and ceramic products has been most gratifying. The willingness of committees and whole associations to come to the bureau and spend a day in discussing problems and preparing programs of work shows not only the interest which these associations have in the bureau, but their confidence in the results to be obtained. These visits to the bureau by the representatives of the technical societies have been of material assistance to the bureau also, in enabling it to conserve the time of its staff and the cost of attending these meetings in other cities. At the same time, however, the staff of the division has attended a great many conferences with

groups and presented the work and secured advice as to its continuance.

The following technical societies and commercial organizations are cooperating with the bureau in one way or another, some in investigative work on specific problems, but the majority in committee work on the broader problems of standardization and establishment of specifications: American Institute of Architects, American Society for Testing Materials, American Society of Mechanical Engineers, American Ceramic Society, National Electric Light Association, National Terra Cotta Society, United States Potters Association, American Vitrified China Manufacturers Association, Hollow Building Tile Association, Refractories Manufacturers Association, American Face Brick Manufacturers Association, Common Brick Manufacturers Association of America, National Paving Brick Manufacturers Association, Wall Tile Manufacturers Association, American Stokers Association, National Glass Distributors Association, American Hotel Association, and Sheet Metal Ware Association.

PUBLICATIONS.

During the year the following reports of work done in the division have been published:

- Effect of variations in heat treatment on the physical properties of vitreous china bodies (H. H. Sortwell), Jour. Amer. Ceram. Soc., August, 1923.
- Impact tests on tableware (H. H. Sortwell), Jour. Amer. Ceram. Soc., February, 1923.
- Technologic Paper No. 227, American and English ball clays (H. H. Sortwell).
- A study of the origin and cause of stones in glass (Herbert Insley), Jour. Amer. Ceram. Soc., June, 1923.
- Technologic Paper No. 234, Methods of measuring the plasticity of clays (F. P. Hall).
- Some qualitative tests on the resistant properties of soda-lime glasses to water (L. A. Palmer), Jour. Amer. Ceram. Soc., April, 1923.
- The weathering of glass containers (K. L. Ford), Jour. Amer. Ceram. Soc., December, 1922.
- Effect of hydrogen ion concentration on clay suspensions (F. P. Hall), Jour. Amer. Ceram. Soc., September, 1923.
- The effect of some substitutes for tin oxide on the opacity of white enamels for sheet steel (R. R. Danielson and M. K. Frehafer), Jour. Amer. Ceram. Soc., May, 1923.
- Disintegration of soda-lime glasses in water (A. E. Williams), Jour. Amer. Ceram. Soc., August, 1922.
- Comparative tests of English and domestic whittings (A. E. Williams and B. J. Woods), Jour. Amer. Ceram. Soc., December, 1922.
- Recommended specifications for limestone, quicklime, and hydrated lime (W. E. Emley and A. E. Williams), Jour. Amer. Ceram. Soc., June, 1923.
- Further studies on cast glass pots (R. F. Geller and A. N. Finn), Jour. Amer. Ceram. Soc., August, 1923.

SIMPLIFIED PRACTICE.

W. A. Durgin.

FUNCTIONS.

The division of simplified practice is cooperating with American industries in furthering a nation-wide program for the elimination of waste in commerce and industry, through reduction in the number of sizes and types of standard products, the abandonment of useless varieties, and the concentration of the attention of manufacturers upon articles of the greatest interchangeability.

GENERAL.

The division of simplified practice is developing rapidly in response to demand from industry and business. A large part of the effort during the year has been given to meeting requests from a wide range of industries for information on the national importance of simplified practice and the available service of the department in this field. Forty-five conferences have been held at Washington, D. C., 81 formal addresses have been made to groups of from 50 to 1,200 individuals, and 21 articles published in the news, trade, and general press. In addition the division has been represented at 50 other meetings of business committees or conventions where some considerable attention was secured.

SIMPLIFIED PRACTICE RECOMMENDATIONS.

Recommendations Printed.

The series of simplified practice recommendations now includes nine items. Two of these, covering paving brick and bedsteads, springs, and mattresses, respectively, have been requested in printed form by a very large number of interested producers, distributors, and consumers. The original paving-brick recommendation was revised for the second time on March 27, 1923, further eliminations reducing recognized types and sizes to 6, as against the 66 styles which were being merchandized only a year and a half ago. Survey of the industry and statement of leading firms unite in emphasizing the great importance of this measure.

Recommendations in Process of Acceptance.

The remaining seven recommendations are in process of formal acceptance by individuals, and as each has the approval of a general conference of all interests it is certain these will be published by early fall. The commodities covered are:

No. 3, Metal lath. Reducing from eighty-odd to 18 styles, with the hearty cooperation of manufacturers, architects, builders, and other interests.

No. 4, Paints, varnishes, and containers. Readoption of the war-time schedule in the manufacture of paints and varnishes, with several additional eliminations of sizes and types of containers.

No. 5, Hotel chinaware. Reduction from over 700 sizes and types to approximately 160 by the cooperative action of the American Hotel Association and the Vitrified Chinaware Manufacturers' Association.

No. 6, Asphalt. Elimination of approximately 90 per cent of the existing grades and varieties in paving and filling asphalts. One producer states that if this could have been accomplished a year ago it would have already resulted in a saving of \$200,000 to his concern alone. There are 22 firms in this business in the United States.

No. 7, Face brick. Adoption of one standard size each for rough and smooth brick, as against the 38 rough and 35 smooth brick varieties previously used.

No. 8, Paper. Eight sizes of paper with their doubles recommended as standards for all general uses. This action of a representative general conference is based almost entirely upon research work of the paper section of the structural, engineering, and miscellaneous materials division, and reports from technical committees representing the paper industry indicate that it will certainly lead to enormous savings all along the line.

No. 9, Wire fence. Elimination of $87\frac{1}{2}$ per cent of the existing styles of woven-wire field and poultry fences and $93\frac{1}{2}$ per cent of the variety in packages and concentration upon that comparatively small portion of the present line which accounts for nearly 94 per cent of the total demand.

In addition to these specific examples, the division has important work under way with many large industries.

SERVICES OF THE DIVISION OF SIMPLIFIED PRACTICE BEING USED BY MANY LARGE INDUSTRIES.

Lumber.

The lumber industry (third largest in America) is working on the standardization of nomenclature, grades, and sizes to secure the advantages of simplified practice and developing a nation-wide correlation of inspection service as a means to protect consumers in the quality and quantity of lumber purchased. It is estimated by experts in lumber matters this combined effort will save \$250,000,000 annually.

Farm Implements.

The manufacturers of farm implements are carrying on a comprehensive program, simplifying and standardizing their products to lower costs and improve service to the farmer. One very large manufacturer states the application of the principle of simplification saved his firm over \$10,000,000 in 1920 and 1921.

Retail Hardware.

The 21,000 retail hardware merchants through their national association are endeavoring to improve their service by reducing varieties, patterns, and sizes in axes, hatchets, hammers, saws, files, wrenches, and many other articles in every-day use by carpenters, mechanics,

and householders. They believe such action will lower prices, and stimulate turnover. Manufacturers and jobbers are responding to these efforts, and are confident the results will be well worth while.

Glass, Paper, Metal, and Wood Containers.

A preliminary meeting was held January 16 of manufacturers, distributors, and users of glass, paper, metal, and wood containers. Resolutions were adopted to make surveys in these respective fields tending toward the elimination of excess varieties and types of containers. A committee was appointed for each group, which will collect the data and submit them to a general committee for collation and tabulation prior to a general conference, which will be convened sometime in the early fall.

Flags.

The manufacturers of United States flags now offer the public nearly 300 different sizes, not one of which conforms to any of the 12 standard sizes promulgated by Executive order in 1916. These manufacturers, however, find they are losing money through this great diversity and are working to produce standard sizes which will be both artistic and commercially practicable. This, they claim, is something the country has not had in the 146 years of its independence.

Hollow Building Tile.

The committee of the Hollow Building Tile Association conferred with the division regarding the calling of a general conference in October to consider the elimination of 23 out of 36 existing varieties in types, sizes, and weights of hollow building tile, and adopting 13 as standards for the industry.

Concrete Products.

The Concrete Products Association and the American Concrete Institute have presented to the division their recommendations for the reduction of variety in sizes of structural and partition units made from concrete. Concrete blocks are now made in 30 different lengths, 20 different widths, and 26 different heights. They propose one height, one length, and two widths. A general conference will be called in October to consider the adoption of these recommendations.

AMERICAN MARINE STANDARDS COMMITTEE.

The formation of the American marine standards committee, at the suggestion of the American Marine Association of New York City in cooperation with this division, opens one of the largest fields for the application of the principles of simplified practice. The committee, through the association, is to consider, encourage, promote, adopt, and promulgate, in cooperation with all interests concerned, any measure, such as standards, rules, or recommendations to bring about simplified practice in the fields of engineering, commerce, and industry, as affects shipbuilding. It is also to cooperate with similar foreign bodies engaged in the study or promotion of simplified or standards of practice, in or affecting the marine field. This committee has under consideration 12 hull, 4 machinery, and 3 ship operation subjects.

SURVEYS IN PROCESS.

Surveys are in process for the following industries: Automotive parts; blankets; range boilers; steam boilers; commercial forms; warm-air furnaces; metal, wood, spice, flavoring extract, coffee, and macaroni containers; paper bags; silk threads; locks, bolts, butts, and shelf hardware; shovels; steel refractories; prepared roofing; paint and varnish brushes; milk bottles and caps; surgical instruments; steel lockers; taps and dies; and pianos.

LIST OF INDUSTRIES SERVED.

Other industries being served are those producing men's, women's, and children's shoes; textiles; railway equipment; hospital supplies; mining supplies; oil-well supplies; plumbing supplies; concrete mixers; registers for warm-air furnaces; household refrigerators; crucible refractories; concrete refractories; cast-iron pipe; copper and brass products; mechanical stokers; machine tools; twist drills; watches and clocks; fish containers; dining-car supplies; hardware, including sheet steel, terneplate, conductor pipe, and cove troughs; loaded shells; safes; linoleum; chemicals; rubber heels; and machinery.

BUILDING AND HOUSING.

J. M. Gries.

FUNCTIONS.

The work of this division includes gathering and distributing scientific, practical, statistical, and other information tending to encourage, cheapen, and improve construction and housing. It covers investigations for use in framing local building and plumbing codes, and a study of problems connected with city zoning. Information on the prices, production, consumption, and stocks of building materials, and on building activity is collected, analyzed, and distributed. Special attention is paid to factors bearing on the housing problem. The work includes studies of building practice, and cooperation with efforts to reduce seasonal operations and otherwise eliminate waste in the construction industries.

GENERAL.

Scope of the Work on Building and Housing.

Construction is one of the largest and most important of American industrial activities, and the people of the United States are vitally interested in having it function efficiently. Not only their industrial progress but their housing and general living standards depend very largely on increasing efficiency in construction. The division of building and housing studies the needs of the industry and their relation to the public welfare. It endeavors to see that these needs are met and the public welfare advanced, partly through its own efforts and by enlisting the aid of other branches of the Federal Government, the work of which can be of constructive value, and partly by presenting its conclusions to the industry itself through the trade press, trade associations, and individuals in the industry.

The work of the division, as pursued during the first two years of its activities, has centered mainly around the elimination of waste. It may be divided conveniently into five groups:

1. "Technical service for municipalities" covers recommendations for local building and plumbing codes and work on city zoning problems. This work has been taken up because of statements of individuals and organizations connected with construction and civic improvement that more information is needed if local regulation of construction is to rest on a sound basis.

2. Current statistical information connected with the building industry is collected and distributed by the division. This work includes gathering building material prices, as paid by contractors in different cities, the publication of figures on building activity, building costs, and building materials, and handling of inquiries in regard to statistics.

3. Economic and statistical studies related to the building industry, and the housing problems of the American people, are also made by the division. A study of seasonal operation in the construction industries, undertaken at the close of the fiscal year, is perhaps the most important activity to be mentioned under this heading.

4. Certain other activities of the division aim at the elimination of waste. In this group lie the work on building practice and co-operation with the division of simplified practice in the standardization of building materials.

5. Service to individual home builders comprises the fifth group. The division has issued articles on home financing, choosing the site for a home, weatherproofing, and other problems of the home owner. It also cooperates with the Architects' Small House Service Bureau, a nonprofit-making organization, in its work of preparing and distributing improved small-house plans, and has contributed to the work of the Better Homes in America movement, whose national advisory council in 1922 and 1923 has been headed by the Secretary of Commerce.

General Condition in the Division.

The organization of the division of building and housing remained substantially the same in form and personnel as during the previous fiscal year. Not only within the division, but also in the make-up of the advisory committees on building codes, plumbing codes, and zoning, there were very few changes. The men who served on these committees during the year are given below, with some of their affiliations.

BUILDING CODE COMMITTEE.

Ira H. Woolson, consulting engineer, National Board of Fire Underwriters, New York, N. Y., chairman; member American Society of Mechanical Engineers and National Fire Protection Association.

Edwin H. Brown, architect, Minneapolis, Minn.; chairman committee on small houses and secretary American Institute of Architects.

William K. Hatt, professor of civil engineering, Purdue University; director advisory board on highway research, National Research Council; and American Concrete Institute.

Albert Kahn, member of American Institute of Architects.

Rudolph P. Miller, former superintendent of buildings, New York, N. Y.; president Building Officials' Conference; member American Institute of Consulting Engineers and American Society for Testing Materials.

John A. Newlin, in charge of section of timber mechanics, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, Madison, Wis.

Ernest J. Russell, architect, St. Louis, Mo.; chairman National Board for Jurisdictional Awards in the Building Industry; fellow American Institute of Architects.

Joseph R. Worcester, consulting engineer, Boston, Mass.; member American Society of Civil Engineers and American Institute of Consulting Engineers.

Frank P. Cartwright, technical secretary.

PLUMBING CODE COMMITTEE.

George C. Whipple, chairman; professor of sanitary engineering in Harvard University, Cambridge, Mass.; member American Society of Civil Engineers and American Public Health Association (fellow).

Harry Y. Carson, research engineer, American Cast Iron Pipe Co., Birmingham, Ala.; member Iron and Steel Institute, American Society for Testing Materials and American Foundrymen's Association.

William C. Groeniger, consulting engineer, Columbus, Ohio; member American Public Health Association, American Society of Sanitary Engineering, and American Water Works Association.

Thomas F. Hanley, Hanley & Co., mechanical engineers and contractors, Chicago, Ill.; member American Society of Sanitary Engineering and National Association of Master Plumbers (chairman of standardization committee).

A. E. Hansen, hydraulic and sanitary engineer, New York, N. Y.; member American Society of Sanitary Engineering, American Public Health Association and American Water Works Association.

William J. Spencer, secretary treasurer of building trades department, American Federation of Labor, Washington, D. C.; member United Association of Journeymen Plumbers.

Albert L. Webster, consulting engineer, New York, N. Y.; member American Society of Civil Engineers and American Public Health Association.

ZONING COMMITTEE.

Edward M. Bassett, lawyer; counsel, zoning committee of New York, N. Y.
Irving B. Hiatt, realtor; former president, National Association of Real Estate Boards.

John Ihlder, housing consultant; manager, civic development department of the Chamber of Commerce of the United States.

Morris Knowles, consulting engineer; from the Chamber of Commerce of the United States.

Nelson P. Lewis, municipal engineer; from the National Conference on City Planning and National Municipal League; past president, American City Planning Institute.

J. Horace McFarland, master printer and civic investigator; president, The American Civic Association.

Frederick Law Olmsted, landscape architect; president, The American Society of Landscape Architects; past president, American City Planning Institute.

Lawrence Veiller, housing expert; secretary and director, The National Housing Association.

The members of these committees individually represent the leading technical bodies and professional societies interested in these fields. These committees meet at frequent intervals, usually in Washington, D. C., to draft reports, and to advise regarding the work in their respective fields done by the staff of this division and the technical divisions of the bureau.

TECHNICAL SERVICE FOR MUNICIPALITIES.

Building Codes.

Completion of the report entitled "Recommended Minimum Requirements for Small Dwelling Construction" was the major accomplishment in this field during the year. In accepting this report from the building code committee, the Secretary of Commerce stated:

This report has been built up by cooperation of the Government and the public, which I feel will appeal to everyone. The committee itself represents the great voluntary organizations most interested in public service in this direction, but beyond this you have consulted with many other associations and you have submitted the report in its preliminary form to over 900 municipal officials, architects, engineers, officials of trade associations, and incorporated their criticisms into its final form. I believe this method of intellectual legislation is unique and gives the report a value far beyond any similar work undertaken to date.

I join with you in the belief that it will be helpful not only through practical use by municipalities in building codes and in promoting greater uniformity in

codes throughout the country, but that with its appendix it will prove directly useful to owners and builders of dwellings generally. * * *

The work was initiated and the committee appointed on account of the fact that building codes and builders frequently fail to recognize modern methods of construction, thus adding to building costs and retarding much needed construction, particularly of dwellings.

The report is believed to represent the most thorough investigation that has yet been made of the engineering and practical side of house building. This subject has never before received even a small part of the expert study that is due it and hence millions of our small houses have been built with needless waste of some materials, yet with neglect of simple precautions necessary for comfort and durability.

This first report of the committee deals with the construction of one and two family houses of masonry, poured concrete, and frame types, the latter including veneer and stucco. The value of such construction in the United States amounted to well over a billion dollars in 1922. It is expected that general adoption of the code, with consequent modification of present unjust and wasteful requirements, will result in substantial conservation of materials and the saving of many millions of dollars.

The committee recommends that building codes permit 8-inch solid brick and 6-inch solid concrete walls for two and one-half and three story dwellings accommodating not more than two families each.

Only about 40 per cent of the present city building codes investigated permit 8-inch brick walls in dwellings two stories high, and but 6 per cent allow three-story dwellings of this thickness. Eight-inch walls of hollow tile, hollow concrete block, or hollow walls of brick are permissible, but may not exceed 20 feet in height with an additional 5 feet to the peak of the gable. Two-family dwellings of frame construction would be limited to two and one-half stories under the recommendations of the committee.

Metal lath and plaster on wood studs properly fire-stopped is approved for party and division walls, but at least every alternate wall in row houses must be 8-inch solid brick or concrete, or 12-inch hollow masonry.

Requirements for quality of hollow masonry units agree fairly well with present practice, but in view of the type of buildings dealt with those for brick were placed somewhat below the medium grade established by the American Society for Testing Materials. The report recommends revised working stresses for timber used in dwellings, based on investigations of the United States Forest Products Laboratory. For other materials experimental work of this bureau was used freely.

Live loads to be required as bases for design are 40 pounds per square foot for floors of wood and 30 pounds for monolithic floors or those of solid or ribbed slabs. Foundation walls of brick are required to be 12 inches thick for excavated inclosures, and those of concrete must be as thick as the walls they support, but not less than 8 inches. Special hollow building tile 12 inches thick is permitted for foundation walls of frame buildings.

In addition to the requirements in the code itself, the appendix contains a mass of valuable information on the quality of materials and methods of workmanship which should be used for good results. This part of the report includes tables showing safe sizes of floor joists and girders, a discussion on protecting lumber against decay, an analysis of methods to be followed to avoid cracking of plaster, advice on furring the inside of masonry walls, and many other matters of interest to the home builder.

The discussion of built-in garages, both in the code and the appendix, is regarded as particularly valuable in view of their comparative novelty and their relation to fire hazards. The report is full and explicit on this point. Proper methods of chimney construction and of fire-stopping are also treated. A number of valuable references are given to pamphlets, easily obtainable, dealing with special points.

Upon completion of the small-dwelling report, the committee entered actively upon preparation of reports dealing with regulations governing live-load assumptions and the construction of masonry walls in buildings of other types.

Extensive data on floor loads in office buildings have been compiled and published in a number of building-industry magazines. Other information has been accumulated which will make possible the issue of a tentative report of the committee's recommendations for floor-load requirements in building codes. A similar report also is in preparation, giving the committee's recommendations for construction of masonry walls. It is planned that both these reports will be widely submitted for critical discussion before the publication of final recommendations.

Plumbing Codes.

The work on plumbing codes has followed somewhat the methods used by the building code committee in preparing the report on small-dwelling construction. The plumbing subcommittee has so far concentrated its attention on problems connected with small-house systems, although much of its work also applies to buildings of all types. A lack of any but the most fragmentary information on the intermittent flow of water, such as is found in a house-drainage system, at once revealed the need of experimental work. A special series of tests with actual plumbing installations was accordingly undertaken by the mechanics and sound division, and the results obtained have permitted the preparation of a report which will have the unique distinction of being the first to be based on scientific knowledge of the problems involved.

The committee has paid attention to the problem of municipal inspection of plumbing, and its code recommendations are accordingly being framed with a view to the manner in which they will be applied in practice. A preliminary report was sent out for comment and criticism to several hundred interested persons throughout the country, and much valuable information was obtained which will be utilized in the final report.

Zoning for Towns and Cities.

The principal work of the zoning committee during the year was the completion of a standard State zoning enabling act permitting

cities to zone. A preliminary edition of this act was issued in August and a revised edition in January. It was used as the basis of bills introduced in 11 State legislatures early in 1923 and several of these acts were passed. The need for such a standard form was very great, as comparatively few States had satisfactory acts. The use of a standard act should not only help simplify the drafting of bills but it should have an important effect in avoiding confusion in regard to the legal status of zoning.

The most minute attention was given to the wording of the act in order to insure as far as possible its standing up under court decisions. It was submitted for suggestions to experts who have been connected with the zoning of the greater part of those municipalities in the United States in which such ordinances are in force. The views of the civic, professional, and commercial organizations most interested were carefully considered, and the act was drawn with existing court decisions in regard to zoning constantly in mind.

The division has maintained what is believed to be the most complete list of zoned municipalities in the United States. Its statement that "15,000,000 people live in zoned cities" on January 1, 1923, was commented on most extensively by the daily, weekly, and monthly press of the country.

It is significant to note that when the advisory committee was formed in September, 1921, there were only 43 zoned municipalities, with less than 11,000,000 inhabitants, in the United States, while on June 30, 1923, there were about 155 zoned cities, towns, and villages, with a population of close to 20,000,000.

CURRENT STATISTICS.

The principal current statistical material compiled by the division is a monthly table of building-material prices for 24 items as paid by contractors in about 50 cities. These are obtained in cooperation with the Bureau of the Census largely from local builders' exchanges. They have been published regularly in an increasing number of trade papers, and are used by the Bureau of the Census in compiling index numbers of the price materials for small frame and brick houses. These retail price indexes for building materials delivered on the job are believed to be the only ones of their kind available.

The division has continued to cooperate with the editor of the Survey of Current Business in obtaining the figures on building activity, building costs and production, and consumption and stocks on hand of the principal building materials. This Department of Commerce publication devotes several pages to these figures each month, and, therefore, serves as an invaluable statistical guide to the current situation for those in the industry as well as for those interested in it indirectly.

Some of the more important figures which are believed to be of the greatest value as an index to conditions were plotted regularly in graphical form and received wide distribution through republication in trade papers of the construction industries and allied fields.

The division has also served as a clearing house for inquiries in regard to statistics collected by other Government departments

that relate to building and building materials, and it has been possible to answer several hundred requests involving information collected elsewhere, either directly or by reference to the proper bureau.

ECONOMIC AND STATISTICAL STUDIES.

This work included a special study in March, 1923, of construction activity and demands for construction in relation to the capacity of the construction industries as measured by the supply of building trades labor, building materials, and transportation facilities. This survey was carried on in response to a request from the President, dated March 3, which stated:

The administration, in one way or another, has the direction of Congress to carry on a very considerable volume of construction work. I would be glad to have the advice of the Department of Commerce as to the policy which ought to be pursued in view of the present economic situation in the building industries, with a view to determining how much to speed up on the construction program to which we are committed.

The division also prepared an article for the Year Book of Commerce on "Construction in 1922," with a special section devoted to the housing situation. The Year Book article on "Construction materials other than lumber" was also prepared in the division.

At the close of the year arrangements were made for the division to take charge of an investigation of seasonal operation in the construction industries, in cooperation with the new construction committee of the President's Conference on Unemployment. The work as first outlined was to include a survey of actual seasonal construction by regions and classes of construction. Seasonal operation in the lumber, brick, cement, and other industries was also to be taken up, together with the effects of seasonal operation on the construction industries themselves, on their workers, and on commerce and public welfare in general. The concluding part of the study was to be concerned with the remedies that have been proposed or that have proven successful in a limited way.

MISCELLANEOUS WORK ON ELIMINATION OF WASTE.

The work outlined under technical service to municipalities and much of that under other headings aims at the elimination of waste. In addition to these other activities, however, the division has endeavored to call the attention of the industry to the savings possible through greater simplification and elimination of dimensional varieties. It has, therefore, assisted the division of simplified practice in that part of its work relating to building materials. It is believed that simplification of dimensional varieties of different materials will permit more rapid construction, reduce loss of time due to inability to obtain materials, permit accumulation of semifinished materials in manufacturing, reduce the cost of doing business for retailers, and allow manufacture for stock, thus reducing seasonal fluctuation in the operations of building-material producers.

The division has encouraged the movement to distribute leasing dates throughout the year, as a single leasing date causes the simultaneous completion of business buildings, apartments, and dwellings, which results in aggravation of the seasonal demand thus artificially created.

Service to Individual Home Owners.

The division has prepared several articles for the benefit of individual families, including "Financing a Home," "Choosing the Site for Your Home," and "Weatherproof Your House." A booklet entitled "How to Own Your Home" was in course of preparation at the close of the year, and will embody the results of some of the economic and statistical studies mentioned above.

The division has actively assisted the Better Homes Demonstration Week held October 9 to 14, 1922, and June 4 to 9, 1923. The Secretary of Commerce is chairman of the advisory council of the Better Homes in America Movement and the chief of the division of building and housing is a member of the council.

The October demonstration homes were conducted in over 500 cities and towns, and it is believed that this figure was exceeded during the June period.

One of the chief aims of the demonstrations was to present well-balanced homes, in which the value of the house, the lot, and the furnishings and equipment were well proportioned. In many cases a special effort was made to show how homes could be improved and housework lessened at an expense within reach of the smallest incomes.

COOPERATION, INFORMATION, AND PUBLICATIONS.

Throughout the year the division has continued to work closely with architectural, engineering, and trade associations, and public officials both in obtaining material for technical investigations and statistics and in distributing them. The importance of such cooperation is shown by the advisory committees on Building Codes, Plumbing Codes, and Zoning. The reports of building-material prices have been obtained from private organizations and the better homes demonstrations were carried out entirely through private initiative.

The work on seasonal operation in the construction industries in collaboration with the construction committee of the President's Conference on Unemployment will itself bring the division in contact with practically all the organizations connected with the construction industry.

The chief of the division is chairman of the committee on construction of the American Statistical Association, which is to arrange a part of the program for the annual meeting of that organization to be held in December, 1923.

In addition to the organizations mentioned above, the division has important contacts with the American Civic Association, American Institute of Architects, The Associated General Contractors, Chamber of Commerce of the United States, National Association of Builders' Exchanges, National Association of Real Estate Boards, National Congress of the Building Industry, National Housing Association, and the United States League of Local Building and Loan Associations. The division is also in touch directly with local and State branches of most of those listed above.

The methods of distributing information have varied with the different branches of work. Charts and other material issued by

the division have appeared in nearly all classes of trade papers connected with building, building materials, and real estate; in the Building and Loan Association News; in the house organs of local organizations, such as chambers of commerce, real-estate boards and builders' exchanges; in the monthly bulletins of Federal reserve banks; and in the real-estate sections of newspapers. In addition, the Survey of Current Business is widely used as a source of statistics on conditions in the building industry.

PUBLICATIONS.

Recommended minimum requirements for small dwelling construction (building code committee), Bureau of Standards, 1923.

Among others, the articles listed below have appeared in current publications and most of them are available in mimeographed form:

Review of building and housing situation in 1922 (John M. Gries), New York Evening Post, December 30, 1922, and syndicate of newspapers.

The home buyer and his problems (John M. Gries), National Real Estate Journal.

Built-in garages (Ira H. Woolson), Fire Protection, Indianapolis, Ind., March, 1923.

Weatherproof your house.

Financing a home—Better Homes in America—Plan Book.

Choosing the site for your home (John M. Gries), Better Homes in America—Plan Book.

Standard State zoning enabling act permitting cities to zone. (Advisory Committee on Zoning), Buildings and Building Management (without footnotes), September 22, 1922; Civic Improvement Items, September, 1922; Iowa Town Planning Association Bulletin, September, 1922; National Real Estate Journal, October 9, 1922.

Work of the division of building and housing (John M. Gries), The Constructor, June, 1923.

List of zoned municipalities, Engineering News-Record, September 28, 1922.

III. REPORTS OF THE OFFICE, OPERATION, AND CONSTRUCTION DIVISIONS.

THE OFFICE.

H. D. Hubbard.

FUNCTIONS.

The work of the office comprises the supervision of the units of the administrative branch; selection, recommendation, and assignment of office personnel; planning and supervision of the bureau's clerical routine (finance, personnel, property and stores, transportation, mail and files, purchase, and information); supervision of the editorial work of the bureau; and of the technical library.

GENERAL.

Scope.

The office division handles the accounting for more than \$2,000,000 receipts and expenditures for equipment, supplies, personnel, travel, and general expenses; the personnel actions and records for the staff of more than 900 members, with approximately 193 grades, titles, and specialties; the accountability records and actions affecting more than 100,000 pieces of apparatus, equipment, tools, and furniture; the procurement, storing, and distribution of scientific and other supplies of more than 4,000 varieties; handling and filing 250,000 communications; maintenance of a technical library of about 25,000 volumes and receiving 616 scientific and other periodicals published in 12 languages; the maintenance of a technical catalogue library of approximately 15,000 volumes, with specialized sources of information for the procurement of the latest types of technical apparatus and materials; examination of 234 manuscripts submitted for publication and the editorial preparation for publication of those accepted and approved for bureau publication; the issuance of 91 scientific, technologic, and other publications (containing 2,622 pages of new matter), and their official distribution through regular channels.

The work of the office division thus comprises a wide range of technical subject matter peculiar to scientific research institutions. The technical nature of the correspondence, certificates, reports, equipment and supplies, books and periodicals, and the collation of technical bulletins and publication of research results all require a clerical staff carefully selected and experienced in the subjects handled. The nature and range of such work involve exacting responsibility and call for a trained staff, effective systems for procedure, and adequate checks to insure promptness and accuracy.

Present Status of the Division's Work.

The work of the office during the year has proceeded very satisfactorily. The simplification of procedure and concentration of work has been carried as far as feasible without unduly decreasing effectiveness. The bureau has, however, responded to the urgent need for assistance in the central offices of the department by the temporary detail of certain clerks to assist during the emergency.

I. FINANCE.

D. E. Thomas.

Functions.

The finance section of the office division records the receipt of appropriations and transfers of funds from other departments; accounts for such funds under respective allotments by means of the order and voucher records; prepares all pay rolls, and keeps current the auxiliary records incident thereto; audits and approves all vouchers for payment; checks the disbursing office voucher abstracts; prepares semimonthly financial statements of bureau funds, and periodic financial reports, etc., called for by the Bureau of the Budget; has the custody of all cash received by the bureau, and compiles the annual estimates and fiscal statistics connected therewith.

Funds.

The regular appropriations of the bureau amounted to \$1,547,360. In addition, \$162,100 was transferred to the bureau during the current year from other departments for cooperative investigational work, and \$9,696.92 was received in reimbursements, making the total funds received this year available for obligation, \$1,719,156.92. A large proportion of the money received from other departments for cooperative work was transferred under the fortifications act of May 21, 1920.

Appropriation Statements.

The following statement shows the amount and object of each appropriation provided for the bureau for the fiscal year 1923, the disbursements during the year, the amount of unpaid orders at the close of the year, and the unexpended balance remaining at the close of business June 30, 1923:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Salaries.....	\$432,360.00	\$396,327.76	\$20,262.99	\$15,769.25
Equipment.....	95,000.00	46,129.78	42,639.28	6,230.94
General expenses.....	75,000.00	54,705.14	15,104.82	5,190.04
Improvement and care of grounds.....	10,000.00	6,182.83	2,161.35	1,655.82
Testing structural materials.....	¹ 182,563.88	154,737.54	18,639.39	9,186.95
Testing machines.....	30,000.00	24,637.09	3,519.35	1,843.56
Metallurgical research.....	² 40,133.04	33,406.56	6,552.43	74.05
Investigation of optical glass.....	25,000.00	20,696.42	829.81	3,473.77
Standard materials.....	10,000.00	7,725.28	1,678.40	596.32
Investigation of textiles.....	25,000.00	19,875.89	1,712.39	3,411.72
Sugar standardization.....	³ 41,800.00	32,445.08	8,563.84	791.08
Gauge standardization.....	40,000.00	34,611.43	1,866.15	3,522.42
High-temperature investigation.....	10,000.00	8,891.31	588.38	520.31
Testing railroad scales.....	40,000.00	35,945.92	1,907.95	2,146.13
Investigation of fire-resisting properties.....	25,000.00	21,499.46	3,286.60	213.94

¹ Includes reimbursement of \$7,563.88.

² Includes reimbursement of \$133.04.

³ Includes reimbursement of \$1,800.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
Testing miscellaneous materials.....	\$30,000.00	\$24,930.37	\$3,272.07	\$1,797.56
Investigation of public-utility standards.....	85,000.00	73,978.81	10,626.93	394.26
Radio research.....	30,000.00	27,042.88	2,762.22	194.90
Industrial research.....	⁴ 249,294.00	198,603.67	19,822.99	30,867.34
Sound investigation.....	⁶ 5,200.00	3,705.48	1,375.54	118.98
Investigation of clay products.....	25,000.00	22,422.74	1,634.87	942.39
Color standardization.....	10,000.00	8,411.61	1,366.77	221.62
Radioactive substances.....	10,000.00	7,675.73	1,773.51	550.76
Standardizing mechanical appliances.....	15,000.00	13,082.63	1,244.62	672.75
Investigation of mine scales and cars.....	15,000.00	7,471.49	4,896.08	2,632.43
Standardization of equipment.....	100,000.00	77,969.09	14,854.99	7,175.92
Appropriations transferred from other departments:				
Aviation, Navy transfer.....	3,300.00	205.29	808.96	2,285.75
Party expenses, Coast and Geodetic Survey.....	11,300.00	161.32	2,364.51	8,774.17
Construction and repair, Bureau of Construction and Repair.....	1,650.00			1,650.00
Engineering, Bureau of Engineering.....	550.00			550.00
Ordnance and ordnance stores.....	550.00			550.00
Investigation of sources of crude rubber.....	42,300.00		265.00	42,035.00
Experiments, ordnance, Navy transfer.....	1,100.00			1,100.00
Automatic rifles.....	2,000.00			2,000.00
Incidental expenses of the Army.....	25,000.00			25,000.00
Subsistence of the Army.....	10,000.00			10,000.00
Clothing and equipage.....	2,500.00			2,500.00
Total.....	1,756,600.92	1,363,478.60	196,482.19	196,640.13

⁴ Includes reimbursement of \$144 and transfers from other departments of \$99,150.

⁶ Includes a transfer from Coast and Geodetic Survey of \$200.

The following statement shows the condition of the appropriations for the two preceding fiscal years at the close of business, June 30, 1923:

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1921.				
Salaries.....	\$432,360.00	\$421,133.68		\$11,226.32
Equipment.....	¹ 95,330.00	89,876.90	\$1,529.16	3,923.94
General expenses.....	75,000.00	69,491.36	3,886.22	2,122.42
Improvement and care of grounds.....	10,000.00	9,944.45		55.55
Testing structural materials.....	125,000.00	124,341.63	149.31	509.06
Testing structural materials (Interior civil).....	2,250.00	1,882.64		367.36
Testing machines.....	30,000.00	29,900.74		99.26
Metallurgical research.....	² 25,163.59	25,018.57		145.02
Optical glass.....	³ 31,000.00	30,837.55	.86	161.59
Additional land.....	47,272.00	47,272.00		
Investigation of textiles.....	⁴ 15,680.00	15,566.97		113.03
Sugar standardization.....	⁵ 31,800.00	31,655.08	11.82	133.10
Gauge standardization.....	⁶ 46,183.54	44,709.00	42.56	1,431.98
High-temperature investigation.....	10,000.00	9,965.62		34.38
Testing railroad scales.....	40,000.00	39,655.31	13.76	330.93
Investigation of fire-resisting properties.....	25,000.00	24,495.43		504.57
Investigation of railway materials.....	15,000.00	14,751.88	4.90	243.22
Testing miscellaneous materials.....	30,000.00	29,918.33		81.67
Investigation of public-utility standards.....	⁷ 85,272.86	85,045.08	33.84	193.94
Radio research.....	⁸ 30,096.00	29,901.96	11.25	182.79
Industrial research.....	⁹ 837,856.88	807,835.63	10,540.31	19,480.94
Sound investigation.....	¹⁰ 7,000.00	6,914.52	51.12	34.36
Investigation of clay products.....	25,000.00	24,519.71	65.83	414.46
Color standardization.....	10,000.00	9,778.90		221.10

¹ Includes reimbursement of \$330 from other departments.

² Includes reimbursement of \$163.59 from other departments.

³ Includes transfer of \$6,000 which is available for the incurring of obligations for the fiscal years 1922 and 1923 received from other departments.

⁴ Includes reimbursement of \$680 from other departments.

⁵ Includes reimbursement of \$1,800 from other departments.

⁶ Includes transfer of \$2,420 and reimbursement of \$3,763.54 received from other departments.

⁷ Includes reimbursement of \$272.86 received from other departments.

⁸ Includes reimbursement of \$96 received from other departments.

⁹ Includes transfer of \$773,877, a large portion of which is available for the incurring of obligations for the fiscal years 1922 and 1923, and reimbursement of 13,979.88 received from other departments.

¹⁰ Includes transfer of \$2,000 received from other departments.

Appropriation.	Total appropriation.	Disbursements.	Liability.	Balance.
FISCAL YEAR 1921—Continued.				
Standardizing mechanical appliances.....	¹¹ \$35,000.00	\$34,622.91	.....	\$377.09
Investigation of mine scales and cars.....	15,000.00	11,763.48	\$22.93	3,213.59
Standardization of equipment.....	15,000.00	9,675.50	.....	5,324.50
Appropriations transferred from other departments:				
Air Service, Army, War transfer.....	450.00	443.83	.....	6.17
Armament of fortification, War transfer.....	3,250.00	3,228.01	5.00	16.99
Manufacture of arms, War transfer.....	1,625.00	1,549.77	29.82	45.41
Ordnance stores ammunition, War transfer.....	1,500.00	1,449.24	23.00	27.76
Experiments, ordnance, Navy transfer.....	5,000.00	4,894.06	.....	105.94
Aviation, Navy transfer.....	50,000.00	46,221.51	2,574.72	1,203.77
Total.....	2,209,089.87	2,138,261.25	18,496.41	52,332.21
FISCAL YEAR 1922.				
Salaries.....	432,360.00	421,194.83	.....	11,165.17
Equipment.....	95,000.00	75,636.32	1,821.27	17,542.41
General expense.....	75,000.00	63,289.60	2,701.90	9,008.50
Improvement and care of grounds.....	10,000.00	9,690.24	12.00	297.76
Testing structural materials.....	¹² 178,035.50	157,273.20	1,271.53	19,490.77
Testing machines.....	30,000.00	28,129.75	2.64	1,867.61
Metallurgical research.....	40,000.00	37,641.98	25.58	2,332.44
Investigation of optical glass.....	¹³ 28,000.00	25,842.39	773.05	1,384.56
Investigation of textiles.....	15,000.00	13,959.70	.....	1,040.30
Sugar standardization.....	¹⁴ 31,800.00	29,904.76	91.40	1,803.84
Gauge standardization.....	40,000.00	37,960.85	.....	2,039.15
High-temperature investigation.....	10,000.00	9,451.75	.....	548.25
Testing railroad scales.....	40,000.00	37,091.04	197.94	2,711.02
Investigation of fire-resisting properties.....	25,000.00	23,082.50	154.63	1,762.87
Testing miscellaneous materials.....	30,000.00	28,409.82	.....	1,590.18
Investigation of public-utility standards.....	70,000.00	69,206.36	117.68	675.96
Radio research.....	30,000.00	28,211.85	.....	1,788.15
Investigation of public-utility standards, 1921-22.....	15,000.00	14,795.07	.....	204.93
Industrial research.....	¹⁵ 468,257.00	344,336.34	15,190.44	108,730.22
Sound investigation.....	5,000.00	4,829.31	.....	170.69
Investigation of clay products.....	25,000.00	23,432.38	.....	1,567.62
Color standardization.....	10,000.00	9,148.48	54.00	797.52
Standardizing mechanical appliances.....	15,000.00	13,737.07	.....	1,262.93
Investigation of mine scales and cars.....	15,000.00	13,383.30	.....	1,616.70
Standardization of equipment.....	100,000.00	88,527.64	460.35	11,012.01
Appropriations transferred from other departments:				
Gauge standardization, War transfer.....	3,000.00	2,738.94	220.00	41.06
Total.....	1,836,452.50	1,610,905.47	23,094.41	202,452.62

¹¹ Includes transfer of \$20,000 received from other departments.

¹² Includes reimbursement of \$3,035.50 received from other departments.

¹³ Includes transfer of \$3,000 which is available for the incurring of obligations for the fiscal years 1923 and 1924, received from Navy Department.

¹⁴ Includes reimbursement of \$1,800 received from other departments.

¹⁵ Includes transfer of \$316,673.66, a large portion of which is available for the incurring of obligations for the fiscal years 1923 and 1924, and reimbursement of \$1,533.34 received from other departments.

2. PERSONNEL.

W. C. Fewell.

Staff.

During the year the bureau staff comprised 342 statutory employees and an average of 554 engaged in research and investigations specially authorized by Congress. The statutory positions include 201 scientific positions, 56 office assistants, 50 engaged in the operation of the plant, and 35 in construction. The personnel for the year averaged 896 regularly appointed employees. There were also on the rolls approximately 38 experts employed on the part-time basis, their services being required for short periods at intervals during the year. They are not, therefore, included as a part of the regular personnel.

Personnel Changes.

There were 1,421 personnel changes during the year. These included 278 separations, 270 entrances, 489 promotions, and 847 mis-

cellaneous changes. The staff and the separations were approximately the same as the preceding year. During the year Dr. S. W. Stratton, director of the bureau, resigned to accept the presidency of the Massachusetts Institute of Technology, having served as director of the bureau since its establishment in 1901. Upon your recommendation, the President appointed Dr. George K. Burgess to the directorship of the bureau. He had served in succession as chief of the section of pyrometry and as chief of the division of metallurgy since the organization of that division in July 1913.

The serious problem of maintaining an adequate staff of efficient workers led the office to study the causes of personnel changes. The results are tabulated by groups according to the class of work.

PERSONNEL CHANGES DURING FISCAL YEAR 1922-23.

Nature of action.	Total.	Analysis.				
		Scien- tific.	Clerical.	Con- struc- tion.	Opera- tion.	Housing simplifi- cation and specifica- tions.
Changes of all kinds, total.....	1,421	897	278	103	118	25
Entrances, total.....	283	159	59	13	43	9
Analysis:						
Permanent appointments.....	165	83	38	13	26	5
Temporary appointments.....	77	46	15	0	15	1
Reinstatements.....	28	24	2	0	2	0
Transfers within bureau.....	13	6	4	0	0	3
Exits, total.....	291	181	53	17	36	4
Analysis:						
Better salaries.....	111	70	22	6	11	2
Returning to school.....	26	25	1	0	0	0
Decreasing force.....	17	10	3	4	0	0
Completion of job.....	57	31	8	2	15	1
Ill health.....	15	7	1	0	6	1
Dismissals.....	14	9	3	2	0	0
Deaths.....	5	1	1	2	1	0
Retirements.....	1	0	0	0	1	0
Transfers within bureau.....	13	7	4	0	2	0
Miscellaneous reasons.....	32	21	10	1	0	0
Miscellaneous, total.....	847	557	166	73	39	12
Analysis:						
Promotions.....	489	335	97	40	12	5
Changes of fund.....	210	141	33	27	9	0
Temporary made permanent.....	31	16	6	1	4	4
Cancellations of appointments.....	42	19	12	3	6	2
Extension of temporaries.....	36	18	11	0	7	0
Amendments of appointment.....	16	13	0	2	1	0
Demotions.....	1	0	1	0	0	0
Changes of designation.....	0	0	0	0	0	0
Changes to per diem status.....	6	5	1	0	0	0
Changes to per annum status.....	9	6	3	0	0	0
Changes of official station.....	5	4	0	0	0	1
Changes of name by marriage.....	2	0	2	0	0	0
Average number of employees.....	896	550	148	122	65	11
Ratio of number of separations to average number employed.....per cent..	31	32	33	14	52	33

Salaries.

The average salary of the employees on the scientific staff for the year was \$1,866; the housing, simplification, and specification staff

\$3,603; the office staff \$1,292; the construction force \$1,472; and the mechanical plant or operating force \$842; and for all employees of the bureau the average salary was \$1,665. The average number of employees in the various divisions during the year, the approximate salaries paid, and the average salary per employee are summarized in the following table:

EMPLOYEES AND SALARIES BY DIVISIONS, 1922-23.

Division.	Average number of employees.	Total of all salaries for year.	Average salary per employee.
All divisions, total.....	896	\$1,491,528	\$1,665
Average salaries by classes:			
Scientific and technical.....	550	1,026,341	1,866
Housing, simplification and specifications.....	11	39,640	3,603
Office.....	148	191,271	1,292
Construction.....	122	179,578	1,472
Operation of plant.....	65	54,698	842
Weights and measures.....	45	80,873	1,797
Electricity.....	98	194,620	1,986
Heat and power.....	78	144,896	1,858
Optics.....	45	91,313	2,029
Chemistry.....	67	147,722	2,205
Mechanics and sound.....	48	92,709	1,931
Structural engineering and miscellaneous materials.....	96	152,807	1,592
Metallurgy.....	43	70,085	1,630
Ceramics.....	30	51,316	1,711
Simplified practice.....	5	20,873	4,175
Building and housing.....	4	11,818	2,955
Standard specifications.....	2	6,949	3,474
Office.....	148	191,271	1,292
Operation.....	65	54,698	842
Construction.....	122	179,578	1,472

Leave of Absence.

The Bureau of Standards again occupies the premier position of the bureaus of the department in regard to the minimum use of sick-leave privileges and ranks third in the minimum use of annual leave. A summary of annual and sick leave granted the bureau employees during the calendar year 1922 is given in the following table:

LEAVE OF ABSENCE GRANTED DURING 1922.

Kind of leave.	Days granted.	Average days granted per employee.
Annual.....	19,708	27.49
Sick.....	3,141	4.38
Total, 1922.....	22,849	31.87
Total for preceding year (1921).....	21,386	33.42

Reclassification.

A law was enacted by Congress during the year to provide for the classification of Government employees within the District of Columbia and in the field service. New job-classification sheets were prepared for employees of the bureau. To insure uniformity in the assigning of grades to the various positions, special committees were

appointed to consider and recommend appropriate grades for the individual job sheets. Special care and study was given in assigning grades. The classification as recommended was based upon the character of the work in accordance with instructions set forth in Bureau of Efficiency Circular No. 1. A summary of the bureau's recommendations to the Secretary of Commerce showing the percentage of increase for the various classes follows:

Class.	Present salaries.	Proposed salaries.	Total increases.	Percentage of increase.	Positions. ¹
Scientific.....	\$1,168,740	\$1,348,360	\$179,620	15.36	533
Office and administration.....	231,660	246,800	15,140	6.5	150
Mechanical.....	207,100	214,520	7,520	3.14	121
Operating plant.....	81,656	85,580	3,924	4.8	76
Total.....	1,689,156	1,895,260	206,104	12.26	880

¹ These figures include employees on a part-time basis who are called on only occasionally for consulting purposes. There will probably be no change in the status of these employees.

3. PURCHASE.

S. W. Caywood.

Orders.

During the year just ended 6,029 orders were issued, comprising 4,485 regular orders for industrial, scientific, and technical materials; 223 exigency orders covering emergency purchases; 267 orders for printed forms, scientific technological papers, and documents; 1,054 travel authorization requests. In connection with the procurement work, 8,806 proposals were sent out to prospective bidders, covering industrial, scientific, and technical materials.

Vouchers.

During the year 6,013 vouchers were received, recorded, distributed, collected, prepared for payment, and passed to the disbursing office. It is the function of the purchase section to see that the voucher is ready for payment, which work involves checking for delivery, quality, quantity, price, description, and method of purchase.

Catalogues.

The purchase section maintains a library of technical catalogues of approximately 15,000 industrial, scientific, and technical catalogues, bulletins, etc., numerically filed, and recorded on card indexes by subject and firm name. The usefulness of this library to the bureau's technical staff in locating articles, data, source of supply, information, compilation of specifications, etc., makes it indispensable to the effective procurement of needed supplies.

4. PROPERTY AND STORES.

G. H. Vaneman.

Stores.

During the year approximately \$76,000 worth of scientific and other supplies were received, checked, and shelved; and supplies to

the value of \$67,000 were dispensed through the technical storerooms of the bureau.

The section's perpetual inventory of stores has the advantage of enabling the storeroom to keep all standard stock of supplies on hand and to avoid the accumulation of dead stock.

Property.

More than 7,000 pieces of apparatus, tools, and other equipment were received, inspected, and stamped with the bureau's inventory numbers, and the necessary accountability records were prepared, passed, and filed.

Shipping.

The bureau's freight and express shipments increase each year. These comprise much delicate and fragile apparatus calling for unusual care in unpacking, inspecting, and distributing. The past fiscal year has reached a maximum of approximately 25 tons per week. A daily average of 11 shipments of instruments and materials were returned to the owners after being tested by the bureau.

By careful study of the best methods of packing each kind of instrument or material, and by using the utmost care in handling fragile apparatus, the breakage in shipments of tested material was reduced to a record minimum of four cases for the entire year. In view of the large proportion of extremely fragile apparatus handled, this result is very gratifying.

Transportation.

An effective schedule of transportation service by motor truck has been maintained without failure throughout the year: (a) By mail truck between the bureau and the Department of Commerce, Post Office Department, and other bureaus and establishments of the Government, and (b) by heavy trucks between the bureau and the express offices, freight depots, and Government buildings. All hauling has been done by the bureau's own trucks, and freight and express have been moved promptly from the depots, avoiding storage and demurrage charges during the entire year. Freight movements have at times been as high as 45 tons per day.

By special arrangement the bureau trucks are now hauling also all freight from the depots to the Department of Commerce, work formerly done by drayage companies. This has effected for the department a considerable saving of expenses formerly incurred for drayage, storage, and demurrage.

The section is cooperating with the automotive power plants section of the heat and power division of the bureau in the matter of testing oils, tires, etc. By this method the gasoline and oil consumption of our trucks has been materially reduced.

5. MAIL AND FILES.

R. W. Lamberson.

Communications.

A daily average of more than 800 pieces of first-class official mail were handled by the mail and files section. About one-half of this mail is of an importance to justify special card indexing. An

effective system provides both writer and subject indexes. Telegraphic communication during the year included the receipt of 1,740 incoming and the dispatch of 1,090 outgoing telegrams. The first-class official mail handled during the year aggregated 244,200 pieces.

Schedules.

The mail and files section operates efficiently on strict time schedule, each essential step in the complete handling of incoming and outgoing mail being graphically controlled. Simple graphic records show the daily magnitude of the several classes of mail received and sent and the scheduled and actual time of all sorting, indexing, and distributing operations.

Improvement and Use of Files.

During the year additional storage space was allotted for the files, and the rearrangement of the noncurrent files thus made possible has resulted in better service. Travel records and order folders have been taken over by this section for filing.

The card indexes are segregated chronologically by years, limiting the daily handling of material during current operations, to strictly current records. The card indexes of the mail are now divided into four groups, each assigned to one clerk, thus speeding up the finding of needed correspondence. An efficient subject classification adopted by the section permits parts of any file to be promptly withdrawn for reference by the experts. The section is now enabled to locate promptly any correspondence received by the bureau since its establishment in 1901, by accountability records of withdrawals filed in place of withdrawn correspondence.

Standard Correspondence Practice.

The mail and files section on the basis of regulations, special orders, and authoritative sources of data concerning standard correspondence practice, compiles, maintains, and distributes a book of Standard Office Practice for the entire clerical work of the bureau. A series of office notes supplements this practice by adding later orders and regulations and reminders as to items needing special attention as ascertained from the daily inspection of the mail. The system has resulted in a uniform standard of quality in the bureau's outgoing correspondence, including reports, certificates, and other material.

General Service.

The mail and files section maintains a complete system of collection and delivery of intrabureau communications for the entire bureau and extending to about 20 separate buildings; acknowledges and refers mail addressed to the bureau in error; supervises the bureau communication facilities, including telephone, telegraph, elevator, and messenger service.

The section supervises the operating staff of the telephone switchboard, the current business of which requires two operators and part time of a third, and 10 trunk lines, 1 tie line, and 267 working stations within the bureau.

6. LIBRARY.

A. Fanti.

Accessions.

During the year 1,347 volumes were added to the library of the bureau, making a net total of 24,683. There were outstanding orders for 388 volumes at the end of the year. The accessions included volumes of important scientific periodicals acquired to complete essential reference sets. There were sent to the bindery 1,081 volumes which have been or will be added to the library.

Periodicals.

A total of 616 periodicals is currently received, 316 by exchange, the remainder by subscriptions. Of the total, 396 are in English, 116 in German, 65 in French, and 39 in other languages. The increase in the number of periodicals over last year is 38. The periodicals received are distributed as follows:

	Subscription.	Exchange.	Total.
American.....	108	135	243
British and other in English.....	59	94	153
French.....	34	31	65
German.....	93	23	116
Others.....	6	33	39
Total.....	300	316	616

The 616 periodicals currently received may be classified by subject as follows: 18 scientific and technical bibliography and abstracts, 64 general science, 16 physics, 39 closely related to physics, 67 general engineering, 62 special fields of engineering, 49 metallurgy, 76 electricity, telephony and radio, 54 chemistry and chemical technology, 14 illumination and radiology, 14 architecture and building, and the remainder in miscellaneous or general technical subjects.

Library Service.

The limited library space available has resulted in some temporary decentralization. While many readers visit the library for consultation and reference to the books, by far the larger proportion of the work has been accomplished by the desk assignment of the standard texts to the specialist group most concerned. Arrangements are pending to allow the library increased space for stacks, magazine racks, and readers' tables. The librarian has, during the year, cleared 5,000 loan charges for book withdrawals from the library and has arranged for borrowing 333 books from the Library of Congress and 53 from other libraries.

It is obvious that the new literature serves as a stimulus to the expert staff, as well as giving information of great practical value in their work. The library is administered by an expert in physics, mathematics, and library science, and it is his aim to keep the specialists of the bureau in touch with the latest literature of their respective fields. Since the library is so essential to the success of the scientific work, the importance of keeping it up to date and thor-

oughly equipped with fundamental texts within the bureau's field can hardly be overestimated.

7. INFORMATION SECTION.

Hugh G. Boutell.

Scope.

The information section collates and disseminates certain technical information, arranges for the official distribution of the bureau's publications and reports covering tests of materials, inspects the incoming and outgoing mail, routes inquiries by letter and telephone, prepares special reports and articles, and interviews general visitors.

Special Reports.

Numerous reports and articles for the technical and popular press were prepared during the year. The greatly increased interest on the part of the general public in the scientific work of the Government caused an unusual demand for accounts of the bureau's technical work written in nontechnical language. Many of these were prepared by the information section in cooperation with those in charge of the various investigations. Forty-eight new letter circulars were issued and the Technical News Bulletin was sent out each month as heretofore.

Directing Inquiries.

Incoming inquiries by mail and telephone were routed to the members of the bureau's staff best qualified to answer the questions, or referred to the proper Government department. These included many questions from newspaper information services, industrial organizations, and private individuals, and involved the handling of a large daily mail.

Publications Issued During the Year.

During the past fiscal year the bureau issued 91 new publications. These comprise 37 scientific papers, 26 technologic papers, 22 circulars, and 6 publications of other series; 39 publications were reissued in revised form or from existing plates.

Tests.

The bureau's work includes a large amount of testing of standards, weights and measures, measuring instruments, and materials. Incidental thereto, there is involved in many cases primary research on the scientific principles underlying such tests, the study of existing methods, and the development of new standard tests of determinate precision. The law requires that a reasonable fee be charged for each test, except when made for the National Government or for State governments, in which case the work is done free. The tests completed during the year for other branches of the Government and the public, together with their value, are summarized in the following table. It should be understood that this table includes only those tests for which all technical procedure, including the payment of fee where a charge is made, was entirely completed during the fiscal year 1922-23. Tests carried out by one section of the bureau in connection with the investigational work of another section or

division are likewise not included. The table, therefore, does not represent all the test work carried out in the various laboratories. For a complete record of the tests completed by each section of the bureau during the year, the work charts given in connection with the reports of each division should be consulted.

NUMBER AND VALUE OF TESTS FOR OTHER BRANCHES OF THE GOVERNMENT AND THE PUBLIC COMPLETED, FISCAL YEAR ENDED JUNE 30, 1923.

Nature of test.	For Government.		For public.		Total.	
	Number.	Value.	Number.	Value.	Number.	Value.
Length:						
Tapes.....	170	\$974.05	131	\$598.35	301	\$1,572.40
Other length tests.....	439	527.05	1,193	1,771.50	1,632	2,298.55
Mass:						
Weights.....	892	463.85	4,085	1,779.60	4,977	2,243.45
Scales and balances.....	850	37,344.30	1	1.00	851	37,345.30
Capacity.....	2,409	1,161.60	7,152	3,928.50	9,561	5,090.10
Hydrometry.....	439	464.00	469	833.10	908	1,297.10
Time.....	202	323.00	263	405.00	470	728.00
Electrical tests.....	461	3,211.50	565	3,209.20	1,026	6,420.70
Photometry ¹	2,157	8,967.00	263	786.75	2,420	9,753.75
Radioactivity.....	1,000	61.60	2,151	17,284.80	3,151	17,346.40
Temperature:						
Clinical thermometers ²	1,141	72.62	16,120	1,333.24	17,261	1,405.86
Other thermometers and miscellaneous ³	810	1,389.80	2,058	5,796.82	2,868	7,186.62
Optical tests:						
Sugar polarimetry.....	1,864	1,864.00	27	87.50	1,891	1,951.50
Other optical tests.....	35	347.20	215	1,330.00	250	1,677.20
Chemical analyses:						
Cement.....	1,471	14,710.00	-----	-----	1,471	14,710.00
Other materials.....	4,886	78,003.00	11	278.00	4,897	78,281.00
Standard samples.....	302	538.50	4,077	8,786.35	4,379	9,324.85
Mechanical instruments and appliances.....	755	3,502.10	73	502.50	828	4,004.60
Aeronautical instrument tests.....	58	1,127.00	7	20.75	65	1,147.75
Physical tests of materials:						
Cement.....	5,239	42,319.25	1	1.50	5,240	42,320.75
Other structural materials.....	1,140	3,656.00	127	340.00	1,267	3,996.00
Miscellaneous materials, including paper, textiles, rubber, leather, etc.....	6,669	25,709.00	440	1,259.50	7,109	26,968.50
Metallurgical tests.....	1,260	3,784.27	21	346.00	1,281	4,130.27
Miscellaneous.....	46	376.00	36	265.50	82	641.50
Total.....	31,695	230,896.69	39,491	50,945.46	71,186	281,842.15

¹ In addition, the bureau inspected 1,640,485 incandescent lamps at various factories for other departments of the Government, the fees for which would amount to \$1,247.58.

² This item represents the number of clinical thermometers tested, whereas the total number submitted was 28,860, the difference being rejected for test because of defective construction.

³ In this item is included a total of 2,679 thermometers tested; the total number submitted was 2,898, the difference being rejected for test.

OPERATION AND CONSTRUCTION.

A. E. Hanson.

FUNCTIONS.

This division operates and maintains the power, heating, and refrigerating plants, installs and repairs electrical and plumbing equipment, and cares for buildings and grounds.

GENERAL.

The operation and construction division might well be called the general service division in that its functions include under routine service the heating, lighting, cleaning, maintaining, and guarding of more than a dozen buildings; operating throughout the year two steam plants for furnishing high and low-pressure steam for laboratory use; manufacturing ice and circulating brine at low temperatures, cooling and circulating water for drinking and laboratory uses; generating, converting, and transmitting electric power from three substations at a dozen different voltages or frequencies; providing stationary and portable storage-battery service; providing high and low pressure air, gas, vacuum, and hot and cold water service; maintaining elevators; caring for lawns, shrubbery, paths, roads, and drainage systems, and propagating and caring for flowers; installing new equipment or making alterations to meet changing requirements; in brief, to furnish every service within the range of the equipment and ability of the personnel of the engineering division to further the scientific and technical work of the bureau.

Although the routine work of providing the above services requires a large personnel of widely diversified training and experience, the work incident to increasing the capacity of the various services, extending the distribution systems, making alterations, building foundations, and installing laboratory equipment requires as much time of all classes of employees of the division, except the janitors and watchmen, as does the routine work of operation and maintenance.

CONSTRUCTION AND REPAIR.

A. E. Hanson.

Mechanical Plant (McIlvane).

Necessary repairs have been made to all steam, electric, and mechanical equipment during the past year. The service of the plant has been further improved by the putting into regular service of a 500-kilowatt frequency changer supplying 3-phase, 60-cycle power and the installation of a 200-kilowatt motor generator set supplying direct current. Other equipment procured for the plant and now in process of installation includes a boiler feed pump; a

350-gallon per minute motor-driven pump for fire protection or emergency house service; a 2-ton refrigerating plant for the Industrial and Kiln buildings; three 50-kilowatt transformers; and remote control switches for increasing the safety of operating high-tension equipment.

Electrical Work (Ludwig).

The electrical section has made necessary repairs or replacements of parts of elevators, motors, generators, switchboards, transformers, lighting fixtures, electric ovens and clocks, storage batteries, and watchmen's clock systems; and replaced burned-out fuses, lamps, and electric circuits. New work done by the section has included removal of temporary wiring and installation of permanent wiring in the center wing, Industrial Building; all laboratories on the north side of the Chemistry Building, wiring of new installations of equipment have included a panel furnace, a rubber mill, tire-testing machine, cranes for the Emery testing machine, sugar laboratories, photo-emulsion laboratory, dynamometers and altitude chambers, and a 200-kilowatt motor generator set. Numerous smaller wiring jobs have included extensions of service and connections of small motors, ovens, regulators, relays, call bells, ventilating fans, lights, etc.

Plumbing and Steam Fitting (Koch).

Necessary repairs have been made to plumbing fixtures, chemical hoods, steam baths, water stills, gas burners and blowers, regulating valves, flushometers, steam and waste traps, thermostats, reducing valves, steam and brine radiators, distribution lines for steam, water, air, gas, vacuum, brine, and ammonia; and expansion valves, bibbs, and joints have been repacked. Installation of new equipment or alterations in laboratories have required the installation of steam and brine radiators, thermostats, regulators, aspirators, condensers, sinks, pipe stands and guard rails, chemical hoods, steam baths, gas burners and blowers, and fire-protection equipment. The above installations and connections to other equipment not installed by this section have required extensions of all pipe distribution systems and installation of new ducts, flues, drains, and ventilating systems.

Miscellaneous (Peters).

Painting during the past year has included the exterior of the North Building, two of the power-plant stacks, the halls in the North and West buildings, 18 laboratories and offices in the Northwest building and several rooms in other buildings. Partitions have been built in the Northwest, South, East, and Industrial buildings and others removed in the East and North buildings. Concrete foundations have been built for more than a dozen installations of heavy equipment; a concrete block wall 75 feet long and 30 feet high was built to act as a sound screen; a concrete floor was laid in the East wing of the Industrial Building and several smaller sections laid in other buildings. A cornice, water table, and stucco were added to complete the sound chamber; work was begun on the extensive alterations and repairs required for the high-tension laboratory; several temporary sheds and buildings including the motor-transport barracks have been removed from the bureau's grounds; necessary repairs were made to skylights, roofs, ventilators, flashings and gut-

ters, doors and windows; broken glass and marble replaced and plastering pointed up; fire equipment inspected and tested; boiler settings repaired.

BUILDINGS AND GROUNDS.

F. A. Peters.

Care of Buildings (Rundell, Fields).

The janitorial work is largely of a routine nature in cleaning the buildings, including offices and laboratories, disposing of rubbish, and keeping sanitary conditions throughout. This section is also called upon to supply laboratories requiring ice, move heavy equipment about the bureau, or assist in the hauling of such equipment from freight stations to the bureau. The bureau has about 25,000 square feet of floor space for each janitor, while 10,000 square feet is considered all the area one man can keep in proper condition.

Guarding (Struks).

The duties of the watchmen consist in making inspections of the buildings to prevent fire, theft, and damage by weather to the property of the bureau. They report to the superintendent's office all matters discovered on their rounds needing attention, such as locks out of order, broken windows, leaking valves and faucets, burned-out lamps, waste of water, gas, or power. They start or stop apparatus at specified times as requested by members of the scientific staff and make record of all employees entering, leaving, or working in laboratories outside of regular hours. Watchmen's rounds are recorded on clocks.

Grounds (David).

During the year a plane-table survey and map were made of the bureau's grounds and buildings by the Coast and Geodetic Survey. One thousand square yards of cinder concrete road were built between the East and Radio buildings, and extending toward Pierce Mill Road. Regrading done around several of the buildings to prevent flooding of basements from heavy storms has resulted in considerable improvement. Several ground drains have been added. Cinders from the boiler rooms have been used to build roads, paths, and automobile parking space. A space 120 feet in diameter has been cleared east of the Industrial Building for the rail-joint investigation. Dead trees have been cut down and wood, together with packing boxes, supplied regularly to our boiler rooms; débris has been cleared; lawns, shrubbery, and flowers have been cared for.

TRANSFER OF CUSTODIAL WORK AND PERSONNEL.

Preliminary to the transfer of the responsibility for the care, maintenance, and protection of the buildings of the Department of Commerce to the superintendent of the State, War, and Navy Department Buildings, a survey was made of the custodial work at this bureau, and a report submitted to the Director of the Bureau of the Budget. It was recommended that the custodial work be left with the Bureau of Standards, as it was handled efficiently, judging from the condition

of the buildings and the reported costs of operation, which are about two-thirds of the cost per square foot of most down-town Federal buildings. However, the Comptroller General ruled that the Bureau of Standards custodial work must be transferred to comply with the act of Congress. The transfer was made effective July 1, 1923.

Larger Custodial Force Needed.

As the necessary heat and light must be furnished, it is evident that the low cost of the bureau's custodial work is largely accounted for by the inadequacy of personnel. This is further shown by the fact that the bureau has about 25,000 square feet of floor space for each janitor, while 10,000 square feet is considered all that one man can properly care for. Increasing the janitorial and watch forces by 50 per cent would still keep the bureau's cost low and insure the keeping of all parts of the buildings in good condition and properly guarded.

IV. RECOMMENDATIONS.

Personnel.

The greatest need of the bureau is the securing and maintaining of scientific and technical personnel of a high grade to whom salaries should be paid commensurate with those obtaining in competitive occupations. It has been found impossible to fill certain very important positions in the bureau, including that of division chiefs, with the grade of men desired because of the low salary scale. It is very important that the proposed new reclassification schedule be put into effect at as early a date as possible to remedy this situation.

Additional Land.

The importance of acquiring the land lying between the bureau's property and Connecticut Avenue has been mentioned several times in previous reports. The importance of this will be realized upon examination of the map near the beginning of this report, and it is extremely necessary to keep control of this property not only to insure a suitable entrance but to provide for the future expansion of the bureau. Moreover, all property in this vicinity is increasing rapidly in value, and it is in the interest of economy to purchase it at the earliest possible moment.

Power Plant.

The original power plant of the bureau was designed to supply two buildings, and for many years its equipment has been utterly inadequate to meet the current needs of the laboratories. In order to provide the necessary steam, electricity, and other facilities, it has been necessary to add two other boiler plants and considerable electrical machinery. A great deal of the power is now bought from the commercial company. The reliability of such service is necessarily not as great as it should be for a research institution where the shutting down of machinery, due to interruptions in the power supply, may result in the loss of valuable data. In the interests of economy and efficiency, a central power plant should be provided as soon as possible. It is believed that the erection of such a plant would result in a very great saving owing to the increase in the reliability of the service and the lower cost of power production.

Care of Buildings.

The number of janitors, laborers, and watchmen available to care properly for the buildings and grounds is quite inadequate; there being, for example, at the bureau one janitor per 25,000 square feet of floor space, as compared with the average of one per 10,000 square feet in the Government service. These figures, however, do not tell the whole story, because, owing to the nature of the work carried on at the bureau, it is even more important than in most Government buildings to care properly for the equipment, and the work necessarily requires a higher degree of intelligence than is usually the case in connection with janitorial service.

Printing and Publications.

The funds provided for printing and publication of the results of the bureau's work have been insufficient to meet the demand for this material for some time, but during the past two years the expansion of the bureau, owing to its extended activities in the specification field, as well as to the increase in its normal output relating to scientific and technical investigations, has made this increasingly apparent. To meet adequately the demand for the publications of the bureau will require additional funds for printing, and it is recommended that an effort be made to increase the bureau's allotment for this purpose, as it seems evident that it is highly desirable to make available to industry satisfactorily and promptly the results of the bureau's work.

New Legislation.

In view of the fact that questions of maintenance, operation, and protection are so closely interrelated with the conduct of technical investigations in the laboratory that it is impossible, for example, to distinguish between the fuel used for heating and lighting and that employed in the conduct of experimental work, it is earnestly recommended that the act of Congress approved February 13, 1923 (42 Stat., 1239), turning over these functions and appropriations to the superintendent of the State, War, and Navy Department Buildings be repealed in so far as it relates to the Bureau of Standards.

The bureau is also interested in legislation relating to uniformity in weights and measures; the approval of weighing and measuring appliances; the use of clinical thermometers; the betterment of railway track, mine, and other commercial scales; the sale of uniform loaves of bread on the basis of weight; and such other matters as will give to the public more satisfactory standards in every field.

Additional Funds for Research.

To keep pace with the urgent demands of industry for the support of fundamental research on which the progress of industry and the prosperity of the country depend, it is highly desirable to urge upon Congress the need of supporting experimental research upon a more extensive scale at the bureau. It is well recognized that the brunt of the cost of industrial research should be borne by industry; nevertheless, there are many important problems of a fundamental nature common to industry as a whole and also specific problems relating to an industry which can be handled best by the active participation of a public research institution, such as the Bureau of Standards. It is in the public interest that many such problems be developed by the participation, in their solution, of a Government laboratory, and I am, therefore, urging substantial increases in the estimates for the coming year.

Respectfully,

GEORGE K. BURGESS,
Director.

TO HON. HERBERT HOOVER,
Secretary of Commerce.

